THE

AMERICAN NATURALIST

VOL. XXXIV. *December, 1900.* NO. 408.

THE STUDY OF MAMMALIAN EMBRYOLOGY.[1]

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THIS article is intended to give a preliminary account of a *Text-Book of Embryology*, upon the preparation of which I have been working for a considerable period. The book is intended especially to meet the needs of the student of human anatomy, but it is hoped to render it suitable for use as a general introduction to vertebrate embryology. The distinctive aim of the work will be to direct the beginner in the practical laboratory study of mammalian embryology, guiding him through an intelligent examination of the external form and of the microscopic sections.

The publication of Foster and Balfour's admirable *Elements of Embryology* gave a great impetus to the science, but it is, unfortunately, many years since the last edition of that work appeared (1883). Duval's *Atlas* is at present the most available guide, but is too elaborate and costly to be within the reach of most students. It is a work which ought to be in every laboratory, for it is a fine monument of well-directed learned industry. Both of these works deal with the embryology

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of the chick, — the one chiefly, the other exclusively, — and furnish little aid for mammalian embryology. Marshall's *Embryology* is on a more comprehensive plan, but as it scarcely passes beyond the general principles of vertebrate embryology it cannot satisfy the needs of anatomical study. There is in these three works the merit of an adaptation to practical laboratory study, but there are no recent manuals of this type. On the other hand, there is, as all morphologists know, an abundance of recent embryological text-books; but all of them, I think without exception, follow the general pattern established by Kölliker in the first edition of his *Entwickelungsgeschichte* (1861), and offer generalized descriptions of the development of the germ-layers, and then of the various organs. A beginner profits more from a presentation of the subject which clings to the actual preparations which he may make for himself. These considerations have led me to the conviction that an introductory work more or less upon the model of Foster and Balfour would be useful. It is such an "Introduction" which I have undertaken.

The plan adopted is briefly as follows:

First, a study of pig embryos of from 9 to 12 mm. Experience has shown that embryos of these sizes can be obtained in considerable numbers from the pork-packing establishments, such as may be found near most large cities. The anatomy of the pig at this stage is readily understood by the student who knows the general anatomy of the adult. Older embryos are more complicated, and yield such long series of sections that the beginner is apt to be discouraged; younger embryos, owing to their spiral twisting, are exceedingly difficult for students to understand when sectioned.

Second, a study of pig embryos of about 17.0 mm. and of the head of an embryo of 20 to 24 mm., which will suffice to render clear the relation of the early embryonic anatomy to the adult structure.

Third, a study of the chick embryo of 20 to 30 hours to illustrate the character of the germ-layers.

Fourth, a study of the fœtal envelopes, including the placenta in man and perhaps also in the pig and rabbit.

Fifth, a study of the genital elements, impregnation, segmentation, etc.

This scheme is not logical in its order, but it seems to me to follow that psychological order which is natural for beginners in embryology who have already studied anatomy. It is, I believe, often a mistake in introducing a pupil to a new subject to sacrifice the natural, and therefore easy, psychological sequence to the artificial demands of a logical arrangement. I hope, therefore, that the scheme adopted will prove advantageous for laboratory work.

Most stress will be laid upon the young mammalian embryo. Figures have been prepared to show several stages of the pig, all magnified eight diameters. To represent the first stage to be studied, a pig of 10.0 mm. has been chosen (Fig. 1). This figure, as well as the others in this article, are woodcuts after pencil drawings. The drawings were made for me by Mr. E. A. Locke with great care and accuracy. The woodcuts were made by Mr. C. L. Albert Probst, of Braunschweig, Germany, and reproduce the original drawings with remarkable and satisfactory success. The German school of wood engraving uses the black line, while the American school uses the white; so that a German woodcut reproduces microscopical textures better than an American, since in our *stained* sections we rely in our studies chiefly upon the dark or stained parts, and these are indicated by the black-line better than by the white-line engraving. There is the further advantage that the cost in Germany is considerably less. The wood engravings combine softness and delicacy of tone with brilliancy of texture, and thus surpass, it seems to me, very considerably even the best "process" engravings. As the number of good figures of sections of mammalian embryos is very limited, and as there is no series of illustrations of systematically chosen typical sections of typical mammalian embryos, it is hoped that the present series will be useful, not only to students, but also as a convenience to advanced workers. On the other hand, it cannot be claimed that the new pictures represent definite original research, because they are intended primarily for text-book use. I have pleasure in acknowledging very valuable assistance

in the identification of parts rendered by Drs. R. T. Atkinson and F. A. Woods, and by Mr. F. T. Lewis and Mr. J. L. Bremer. Mr. Lewis has made also several dissections of the cephalic nerves, and Mr. Bremer models by Born's method of the brain and pharynx. I hope the results of these researches will be published separately.

I wish also to express my appreciation of the great excellence of the recent text-books of embryology which have appeared in England, France, and Germany, although I venture to point out that they differ in plan from the proposed new book.

A mammalian embryo may be conveniently regarded as having assumed its typical class organization at the time when the limb-buds have just become distinct appendages, as found in pig embryos of 9 to 12 mm. At this stage a mammalian embryo is readily distinguished from that of any other class of vertebrates, and the differentiation of the anlages[1] of all the important organs is accomplished so that these anlages can be identified with certainty and their genetic relations to the adult structures can be clearly grasped by the student. At the same time, although the anatomical differentiation is well advanced, the histological differentiation has made very little progress, so that the stages in question are particularly instructive to beginners. Fig. 1 represents a pig embryo of 10 mm. The student should make a careful and thorough study of the external form, noting the following features. The head, which is very large in comparison with the body, forms as a whole nearly a right angle with the back, so that dorsal outline of the head forms a distinct though rounded angle with that of the back; this angle marks the position of the neck-bend, and corresponds to the junction of the brain with the spinal cord. The neck-bend is one of the most marked and distinctive characteristics of the mammalian embryo, being much less marked in birds and reptiles, and being absent in amphibians and fishes. It is probably closely correlated with the cramping of the ventral cervical region, which leads to the formation of the cervical

[1] Anlage is from the German, and has been adopted as a technical term to designate the first accumulation of formative material recognizable as the commencement of an organ, structure, or part in a developing organism.

sinus (*C.S.*), and to the disappearance of the second to fourth gill-clefts. The neck-bend is so great that the mandibular and nasal regions of the embryo are closely appressed to the cardiac region of the body proper. The cephalic region has a second flexure, the head-bend proper, which marks the site of the mid-brain, and in the figure appears as a rounded angle obliquely above the eye. From the mid-brain one axis, hori-

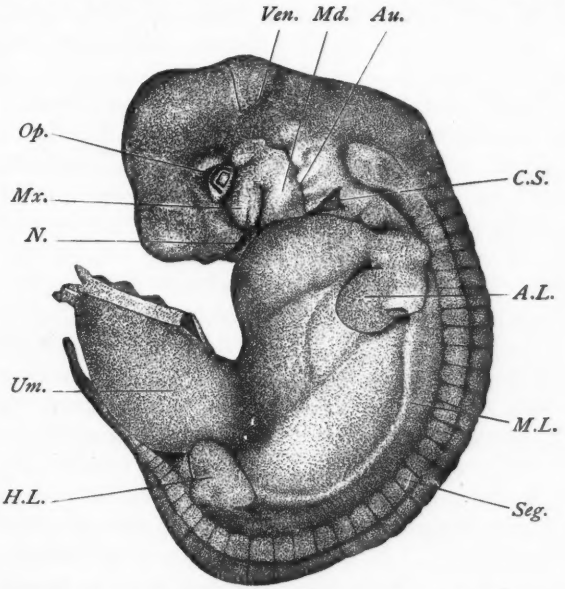


FIG. 1.—Pig embryo of 10 mm. *A.L.*, anterior limb; *Au.*, auditory, or first, gill-cleft; *C.S.*, cervical sinus; *H.L.*, hind limb; *Md.*, mandibular process; *M.L.*, milk-line; *Mx.*, maxillary process; *N.*, nasal pit; *Op.*, eye; *Seg.*, muscular segment; *Um.*, umbilical cord; *Ven.*, floor of fourth ventricle (medulla oblongata). × 8 diams.

zontal in the figure, extends backward through the region of the fourth ventricle, or hind-brain (*Ven.*), to the neck-bend, while the other axis extends vertically downwards to the region of the fore-brain, which is marked by a rounded protuberance in the outline of the head. The dorsal outline of the body proper forms a long sweeping curve, ending in the tail; this dorsal curvature is another characteristic of the amniote embryo, the back in the embryo of fish-like forms being

relatively straight. It is thus brought about that the dorsal side of the embryo is two or three times as long as the ventral. From the ventral side springs the large umbilical cord, the connection of which with the body occupies practically the entire length of the ventral median line of the abdominal region proper. Above the umbilical cord the protuberant outline of the cardiac region passes below the nasal (*N.*) and mandibular (*Md.*) regions toward the cervical sinus (*C.S.*). The long tapering tail extends near the umbilical cord.

The surface modeling of the embryo offers important features. Beginning with the head, we observe first the shallow depression, constituting the nasal pit (*N.*). The eye (*Op.*) is entirely without lids; the lens appears in the center and is surrounded by the outlines of the optic vesicle. The small size of the eye is a characteristic of the mammalian embryo; by which it differs from all sauropsidan forms, but in certain other mammals the embryonic eye is slightly larger than in the pig. Below the eye is the maxillary process (*Mx.*), which is destined to form the greater part of the upper jaw; the anterior boundary of the maxillary process is marked by a shallow depression, the lachrymal groove, which runs from the angle of the eye (*Op.*) to the nasal pit (*N.*). The mandibular process (*Md.*), out of which the lower jaw is developed, is bounded in front by a groove separating it from the maxillary process, and behind by a second groove (*Au.*), the anlage of the future meatus auditorius externus. This groove marks the boundary between the mandibular process and the first or hyoid branchial arch, and is itself the ectodermal member of the first gill-cleft. The fourth ventricle (*Ven.*) or cavity of the hind-brain, having very thin walls for its roof, can be readily distinguished. The thickened floor of the fourth ventricle is the anlage of the medulla oblongata. The cervical sinus (*C.S.*) is an area of invagination, presenting at this stage a triangular outline; within the sinus are found the external or ectodermal terminations of the second and third gill-clefts. The territory of the mandibular process and cervical sinus corresponds to the pharyngeal region. It is the site of some of the most

important, interesting, and complicated developments by which the embryonic is changed into the adult anatomy.

The body of the embryo shows the position and number of the segments (*Seg.*) by the external modeling. Both limbs are well advanced, the anterior (*A.L.*) more so than the posterior. From the base of the front to the base of the hind limb extends the milk-line (*M.L.*), curving so as to be nearly parallel to the dorsal outline of the body. Along this line the mammary glands are ultimately developed. Extending across the body are several shadowy lines, shimmering through the translucent body-walls. One marks the position of the embryonic diaphragm; it extends from the upper edge of the anterior limb obliquely downwards towards the edge of the umbilical cord. Another, which extends in a nearly straight line from limb to limb, marks the ventral edge of the large Wolffian body or mesonephros, the dorsal limit of which is approximately indicated by the milk-line (*M.L.*). The outlines of the smaller left dorsal lobe of the liver are distinct, and mark out a pointed area immediately below the fore limb (*A.L.*).

Of the remaining figures, 2 to 7 represent six transverse sections through a pig embryo of 12.0 mm. But the position of the sections can be easily followed with the aid of Fig. 1, which represents a slightly younger embryo. The plane of the sections would be indicated by a nearly horizontal line across Fig. 1. The sections are ten microns in thickness, and are 966 in number, not 1200, as the student might expect. The discrepancy is due to the shrinkage of the embryo when imbedded in paraffine. The shrinkage is always very great, and in the case of embryos causes a loss of almost 20 per cent in the length; but as it seems to take place uniformly throughout the embryo, it causes no distortion, so that the embryo in paraffine is an exact though greatly reduced copy — so to speak — of the living embryo. It should be remembered that no correct measurements of the size of organs or cells can be obtained from sections made by the paraffine method. This limitation upon the use of sections is too often forgotten.

The six transverse sections chosen were selected to show the most important points in the structure of the embryo, as

far as the upper part of the abdomen. The organs of the pelvic end of the abdomen and the character of the muscles can be more advantageously studied in other series and stages.

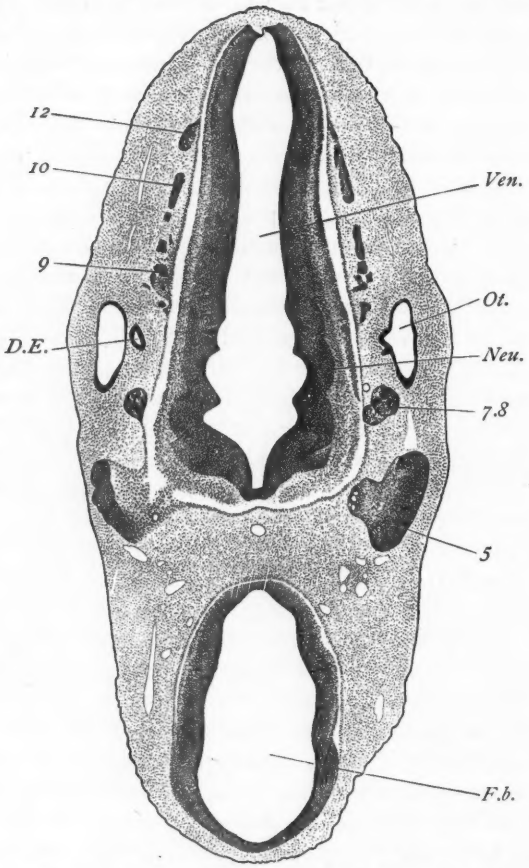


FIG. 2. — Pig embryo of 12.0 mm. Series No. 5. Transverse section 185. *D.E.*, ductus endolymphaticus; *F.b.*, fore-brain; *Neu.*, neuromere; *Ot.*, otocyst; *Ven.*, hind-brain (fourth ventricle); *5*, trigeminal nerve; *7.8*, acustico-facial nerve; *9*, glossopharyngeal nerve; *10*, vagus nerve; *12*, hypoglossal nerve. × 22 diams.

Fig. 2 is at a level about halfway between the eye and the highest point in Fig. 1; it passes, therefore, through the fore-brain (*F.b.*) and the fourth ventricle (*Ven.*) or cavity of the

hind-brain. The section is bounded by the thin layer of epidermis, between which and the brain-walls there is a large amount

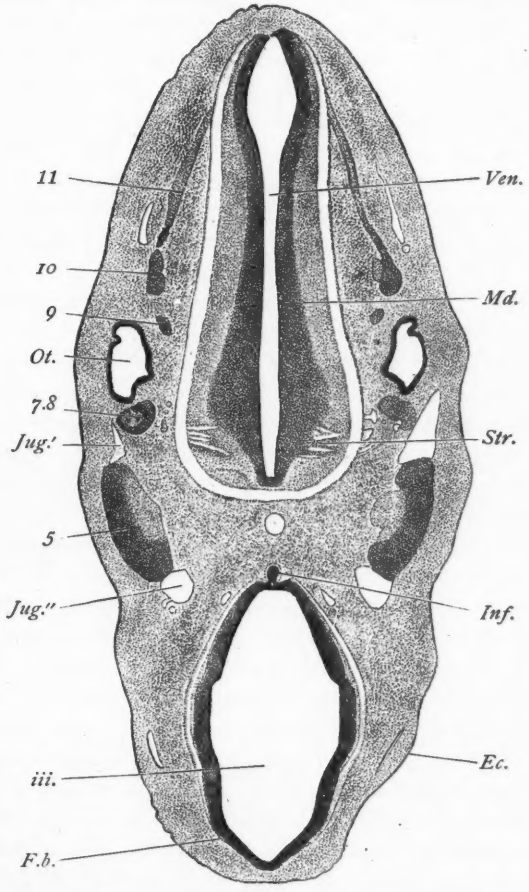


FIG. 3.—Pig embryo of 12.0 mm. No. 5. Transverse section 195. *Ec.*, ectoderm; *F.b.*, forebrain; *Jug.'*, *Jug.''*, jugular vein; *Inf.*, infundibular gland; *Md.*, medulla oblongata; *Ot.*, otocyst; *Str.*, striæ acusticæ; *Ven.*, cavity of hind-brain; *5*, trigeminal ganglion; *7.8*, acustico-facial complex; *9*, glossopharyngeus; *10*, vagus; *11*, accessarius; *iii.*, third ventricle of the brain. × 22 diams.

of mesenchymal tissue. Alongside the hind-brain lie a series of important structures imbedded in the mesenchyma, which

are identical upon the two sides, although they differ in the section, as the plane of cutting was not symmetrically transverse for the head. These structures are in the following order: *5*, the trigeminal ganglion; *7.8*, the acustico-facial ganglion complex; the otocyst, *Ot.*, with upon one side the separated ductus endolymphaticus, *D.E.*, and upon the other side the opening of the ductus displayed by the section; *9*, the glossopharyngeal ganglion; *10*, a portion of the vagus ganglion; *12*, one of the hypoglossal ganglia. Upon the left side of the figure the connection of the trigeminal ganglion with the angle of the wall of the hind-brain is demonstrated; by this connection and by its large size the trigeminal ganglion may always be identified in the embryo. The brain-wall has a thin outer layer both in the hind-brain and mid-brain; this is the outer neuroglia layer (Randschleier of His) and is conspicuous from the absence of stain; inside of the external layer the wall of the brain is crowded with nuclei, and therefore appears deeply stained in the preparation. Three neuromeres (*Neu.*) appear in the section, each marked by a concavity on the inner side of the brain-wall.

Fig. 3 is from section 195, and therefore ten sections below Fig. 2. It is given to show three points not shown in the preceding illustration: 1, the spinal accessory nerve root (*11*) arising from the cervical (in the figure, upper) end of the hind-brain and running forward to join the vagus ganglion; 2, the trigeminal ganglion with the internal jugular vein, which is cut twice (*Jug.'*, *Jug.''*), abutting close against it, — a very characteristic relation (this vein takes a sinuous course along the side of the hind-brain, for it passes inside the twelfth, eleventh, tenth, and ninth nerves, then outside the otocyst and the seventh-eighth nerve, and inside the fifth); 3, the infundibular process or gland (*Inf.*), springing from the floor of the fore-brain (*F.b.*). Attention may also be called to the structures (*Str.*), resembling the striæ acusticæ, but which seem to be rather the fibres of the lateral root of the facial.

The next figure (4) is from a lower level. The section passes through the eyes, the upper end of the auditory cleft (Fig. 1, *Au.*), and the upper cervical region of the spinal cord. The

spinal cord is clearly divided into a dorsal (*D.Z.*) and a ventral zone (*V.Z.*) on each side; the two dorsal zones are connected

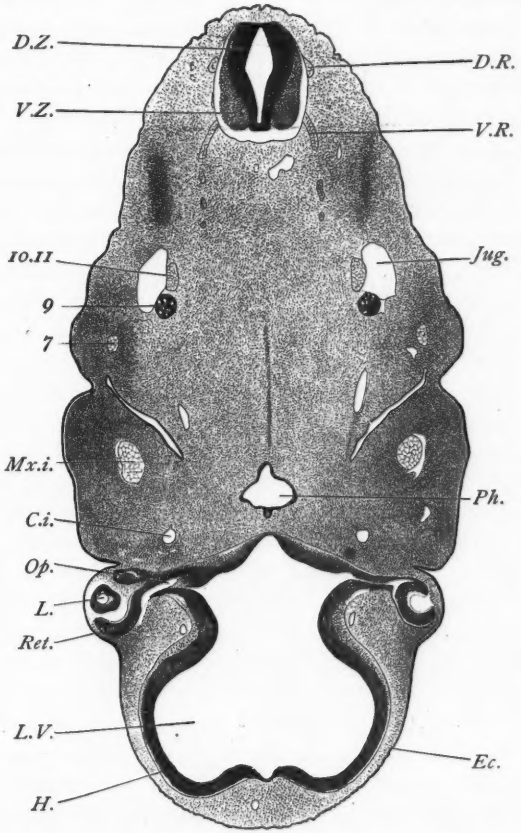


FIG. 4.—Pig of 12.0 mm. No. 5. Transverse section 245. *C.i.*, internal carotid artery; *D.R.*, dorsal root of spinal nerve; *D.Z.*, dorsal zone of spinal cord; *Ec.*, ectoderm; *H.*, cerebral hemisphere; *Jug.*, internal jugular vein; *L.*, lens; *L.V.*, lateral ventricle; *Mx.i.*, inferior maxillary nerve; *Op.*, optic nerve; *Ph.*, pharynx; *Ret.*, retina; *V.R.*, ventral root of spinal nerve; *V.Z.*, ventral zone of spinal cord; 7, facial nerve; 9, glossopharyngeal ganglion; *10.11*, vagus accessorius nerve. × 22 diams.

across the median line by the thin deck plate, and the ventral zones similarly by the thin floor plate. The lower or ventral limit of the dorsal zone is marked externally by the entrance of

the dorsal or ganglionic root, internally by the lateral angle of the central cavity, shown in the section. In the ventral zone the development is more advanced, — the three primary layers in the walls of the neuraxis (or medullary tube) being clearly differentiated, namely: the light outer neuroglia layer; the middle layer, commonly called the mantle layer, but which might be better named the neurone layer; and, finally, the innermost or ependymal layer. These three layers are primary and appear throughout the entire brain and spinal cord. The separation of the dorsal and ventral zones is of fundamental morphological importance, and their characteristics must be clearly understood before the anatomy of the brain is studied. The ventral zone contains all the neurones from which fibres arise forming the ventral nerve root (*V.R.*). Following downwards in the figure we come to the section of the jugular vein (*Jug.*), just inside of which lies the common trunk (*10.11*) of the united vagus and accessorius nerves, and also the lower part of the glossopharyngeal ganglion (*9*). Lower down and nearer the ectoderm lies the facial nerve (*7*), and again still lower is the large trunk of the inferior maxillary (*Mx.i.*), or mandibular branch of the trigeminal nerve. Between the two nerves last mentioned is a long oblique slit, which is found at another level to communicate with the pharynx (*Ph.*); this slit is the inner or entodermal portion of the first or auditory gill-cleft, and is the anlage of both Eustachian tube and of the cavity of the tympanum. Its outer (in Fig. 4, upper) end lies near the bottom of an ectodermal groove; this groove (Fig. 1, *Au.*) divides the mandibular process from the hyoid arch, and is the anlage of the meatus auditorius externus. The hyoid arch is marked in Fig. 4 by the facial nerve (*7*) and the arched overlying ectoderm. The internal carotid artery (*C.i.*) appears near the optic nerve (*Op*). External to this artery lies the superior maxillary nerve, which, however, does not show in the figure. The vesicular lens (*L.*) and the cup-shaped retina (*Ret.*) of the eye can be readily identified. The fore-brain has begun to form two lateral expansions, the cavities of which ultimately become the lateral ventricles (*L.V.*) of the brain, and the walls of which are the anlages of the hemispheres (*H.*).

Fig. 5 is from section 321, and is therefore considerably lower down in the series than the section represented in

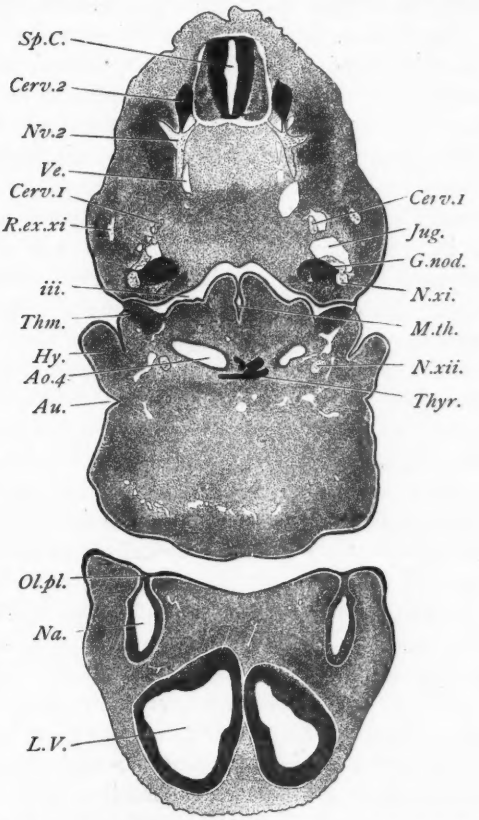


FIG. 5.—Pig of 12.0 mm. No. 5. Transverse section 321. *Ao.4*, fourth aortic arch; *Au.*, ectodermal depression of the first or auditory gill-cleft; *Cerv.1*, first cervical nerve; *Cerv.2*, ganglion of the second cervical nerve; *G.nod.*, ganglion nodosum (lower vagus ganglion); *Hy.*, hyoid arch; *Jug.*, jugular vein; *L.V.*, lateral ventricle; *M.th.*, median thyroid duct; *Na.*, nasal pit; *Nv.2*, second cervical nerve; *N.xii.*, hypoglossal nerve; *N.xi.*, spinal accessory nerve; *Ol.pl.*, nasopharyngeal plate; *R.ex.xi.*, ramus externus accessorii; *Sp.C.*, spinal cord; *Thyr.*, median thyroid; *Thm.*, thymus; *Ve.*, vein; *iii.*, third gill-cleft of the right side. × 22 diams.

Fig. 4. It passes through the cervical sinus and olfactory pits (compare Fig. 1), and therefore also through the spinal cord of the neck. The section comprises two distinct unequal parts:

the first and larger is the section of the cervical, pharyngeal and mandibular regions; the second and smaller is the section from the tip of the low bent head. The spinal cord (*Sp.c.*) in the upper part shows clearly both the three primary layers of its walls and the division into dorsal and ventral zones. The outermost layer is very lightly stained, and may be, perhaps, best defined as the anlage of the white matter. The inner layer is deeply stained, while the middle layer (mantle or gray stratum) is intermediate in color. The nerve cells develop most abundantly and rapidly in the ventral part of the mantle layer, which is consequently more enlarged than the dorsal part and has caused a bulging sidewards and downwards of the ventral zone. The ganglion (*Cerv.2*) is the second cervical; it sends a root upward to enter the dorsal zone of the spinal cord, and a tract downward to join the ventral root, thus constituting the second spinal nerve (*Nv.2*), which subdivides almost at once into a dorsal and a ventral ramus. Between the dorsal summit of the ganglion and the spinal cord there is a small bundle of nerve fibres, not shown in the figure. These fibres constitute the commissural trunk of the eleventh nerve. The third gill-cleft (*iii.*) is cut almost symmetrically, and extends from the median line to the edge of the section; it is lined throughout by the entoderm, which at the end of the cleft on each side has met and fused with the ectoderm to form an epithelial membrane (Verschlussplatte), which closes the cleft laterally. All vertebrate embryos probably have their gill-clefts at an early stage all closed by a similar membrane; but, whereas in fishes and amphibians the membrane is soon broken through, in mammals, on the contrary, it remains intact, and the clefts are, it is thought, normally always imperforate. At the end of the cleft the entoderm has undergone a special growth, forming a distinct mass (*Thm.*) on the side of the cleft towards the head. This entodermal structure is the anlage of the thymus, and is already penetrated by small blood vessels, which are perhaps not capillaries but sinusoids. The third gill-cleft extends to the bottom of the cervical sinus, a large and deep depression of the outer surface, clearly shown both in Figs. 1 and 5. The sinus is bounded cephalad by the large and

protuberant first or hyoid branchial arch (*Hy.*), and this arch is separated from the mandibular region by a groove (*Au.*) or ectodermal depression, which is later transformed into the meatus auditorius externus. In mammals there are four pairs of gill-pouches, or so-called clefts, all of which are lateral diverticula of the pharynx. Owing to the curvature of the pharynx these diverticula are brought to different levels, and into different planes in the pig embryo at the stage we are considering; hence in a series of sections the various gill-pouches are encountered in different portions of the series, and thus it occurs that only one pouch, the third, is shown in the section. The student should clearly understand that the median region of the two-thirds gill-pouches in Fig. 5 is the pharynx proper, and that it gives rise to the anlage of the median thyroid, of which both the stalk (*M.th.*) and the glandular portion (*Thyr.*) appear. Just above the third gill-cleft may be seen the large, darkly stained lower ganglion (ganglion nodosum) of the vagus nerve (*G.nod.*), and just above the ganglion is situated the section of the jugular vein (*Jug.*). Close to the ganglion on its ectal side appear two fibrous nerve trunks, of which the one nearest the pharynx is the accessorius or eleventh nerve (*N.x.i.*), while the other nearest the jugular vein is the hypoglossus, which reappears (*N.xii.*) below the aortic arch. A little above the jugular vein is the section of the first cervical nerve (*Cerv.I*), laterad from which is the external branch (*R.ex.xi.*) of the spinal accessory nerve. This branch in the adult innervates the sternocleido-mastoid and trapezius muscles.

The lower part of Fig. 5 represents part of the head and shows the two nasal fossæ (*Na.*) closed towards the mouth side by the olfactory plate (*Ol.pl.*), an epithelial membrane somewhat similar to the closing plate of a gill-cleft. On the dorsal side of the olfactory fossæ — below in Fig. 5 — the cerebral hemispheres are cut, their darkly stained wall bounding on each side the large lateral ventricle (*L. V.*).

The next section figured is No. 470, and is therefore much lower in the series. It was selected in order to show the anterior limb-buds, the ducts of Cuvier, and the heart. The

position and shape of the limb anlages are shown in Fig. 1, and the section demonstrates that they are formed by mesoderm, with a thin covering layer of ectoderm. The mesoderm is

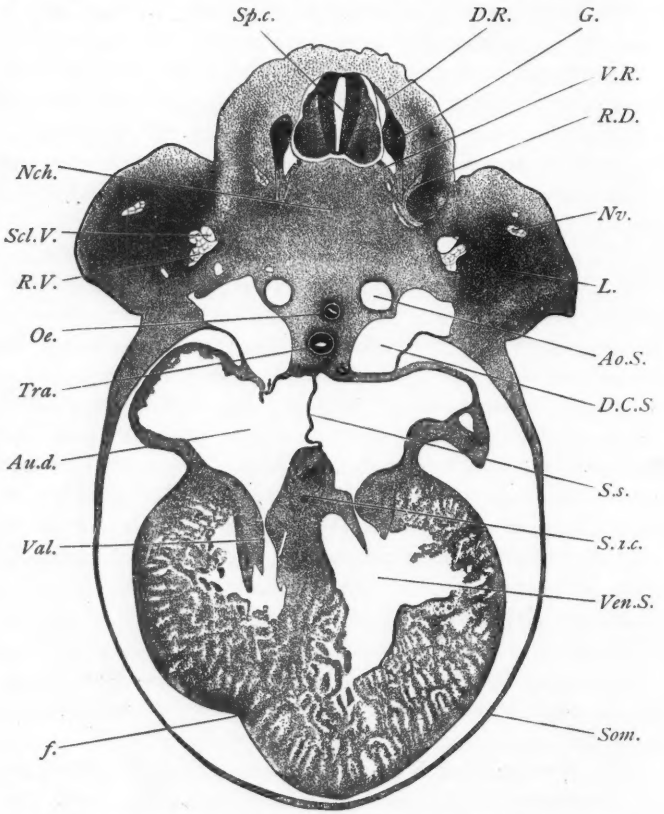


FIG. 6.—Pig of 12.0 mm. No. 5. Transverse section 470. *Ao.S.*, left dorsal aortic trunk; *Au.d.*, right auricle of the heart; *D.R.*, dorsal root of spinal nerve; *D.C.S.*, left ductus Cuvieri; *f.*, external groove between right and left auricles of the heart; *G.*, ganglion of spinal nerve; *L.*, anlage of fore-limb; *Nch.*, notochord; *Nv.*, nerve of limb; *Oe.*, œsophagus; *R.D.*, ramus dorsalis of spinal nerve; *R.V.*, ramus ventralis of spinal nerve; *S.a.c.*, septum of auricular canal; *Scl.V.*, subclavian vein; *Som.*, somatopleure; *Sp.c.*, spinal cord; *S.s.*, septum superius; *Tra.*, trachea; *Val.*, atrio-ventricular valve; *Ven.S.*, left ventricle; *V.R.*, ventral root of spinal nerve. × 22 diams.

very little differentiated, none of the skeletal elements being yet formed. The nerves and blood vessels are growing into

the limb; the nerves are the rami ventrales (*R.V.*) of spinal nerves, and form branches within the limb; one of these branches, as yet unidentified, is shown at *Nv.* The vein *Scl.V.* is the so-called subclavian or axillary vein, a branch of the jugular, as explained below. The lower part of the section is occupied by the large heart lying in the pericardial chamber. The body-wall (*Som.*), or somatopleure, which forms the outer covering of this chamber, is quite thin, and without a trace of muscular or skeletal structures. The heart consists of two auricles and two ventricles. The auricles have thin walls and are separated from one another by a very thin membrane, the septum superius (*S.s.*). The right auricle (*Au.d.*) receives upon its dorsal side the opening of the vein or duct of Cuvier, this opening being guarded by valves; of these valves, the one towards the median line disappears, but the other, towards the right of the embryo, persists to form both the Eustachian and Thebesian valves of the adult. The corresponding opposite vein, or left duct of Cuvier (*D.C.S.*), is almost symmetrically placed, but does not have any communication with the left auricle, being instead connected at a lower level by a transverse venous trunk with the ductus Cuvieri of the right side. The upper portion of the left duct (*D.C.S.*) is seen in the section to be somewhat constricted off from the lower portion, and in fact it shows the jugular vein of the head at its actual junction with the ductus. The ventricles of the heart are much larger than the auricles, and the left ventricle (*Ven.S.*) is already larger than the right; the external groove (*f.*), which marks the boundary between the two ventricles, is clearly shown by the section. The trabecular structure of the ventricles is well developed and affords a diagnostic mark by which the ventricles, however cut, may be easily recognized in sections. The development of the trabeculæ corresponds to the formation of the blood sinusoids of the heart, to which I have recently directed attention. The constricted region of the heart, which connects the auricles with the ventricles, is known as the auricular canal. A broad partition (*S.a.c.*) divides the canal into right and left channels, and at the ventricular ends of these channels the formation of atrio-ventricular valves

(*Val.*) is well advanced. The dorsal or trunk region of the section is formed chiefly by the more or less dense mesenchyma. It includes important structures. The spinal cord (*Sp.c.*) resembles that in Fig. 5, but is both larger and more differentiated. The fundamental morphological characteristics of a spinal nerve are well illustrated by the left nerve of Fig. 6. The dorsal root (*D.R.*) bears the ganglion (*G.*) and is joined a little below the level of the cord by the ventral root (*V.R.*) to form a single nerve trunk, which, however, soon subdivides into its two primary branches; the first or dorsal branch, ramus dorsalis (*R.D.*), bends at an acute angle upwards and outwards; the second or ventral continues downward and curves into the limb; owing to this curvature it must be traced through adjacent sections, but in Fig. 6 it can be seen again (*R.V.*) at the base of the limb, where it crosses the subclavian vein (*Scl.V.*). Some distance below the spinal cord is the small notochord (*Nch.*). Much lower, and between the two ducts of Cuvier, appear the œsophagus (*Oe.*) and trachea (*Tra.*), each a ring of entodermal epithelium with commencing condensation of surrounding mesenchyma. This condensed tissue is the anlage of the future submucosa and muscularis. Above the œsophagus, to the right and left, appears the dorsal aortic trunk, of which the left only (*Ao.S.*) is completely retained throughout life. It should be noted that the blood vessels, including the largest, have at this stage only endothelial walls, the adventitial and muscular coats being added later. *All* blood vessels are endothelial chambers, and this fundamental conception ought to be made clear to the student.

We now pass to a section (No. 633) well below the heart, in order to study the characteristics of the Wolffian body, stomach, and liver. At this level, as comparison of the figures will show, the body of the embryo has its greatest dimensions. The upper edge (*Um.*) of the umbilical cord also appears in this section. The spinal cord, with the ganglia and nerves, presents essentially the same features as in Figs. 5 and 6. The notochord (*Nch.*) forms a small circle in section and is surrounded by an area over which the mesenchymal cells are more crowded or condensed than elsewhere. The condensed

mesenchyma is the anlage of a vertebra (*Vert.*). It is more expanded laterally than dorso-ventrally. In the median line below the notochord is the large dorsal aorta (*Ao.*), which is

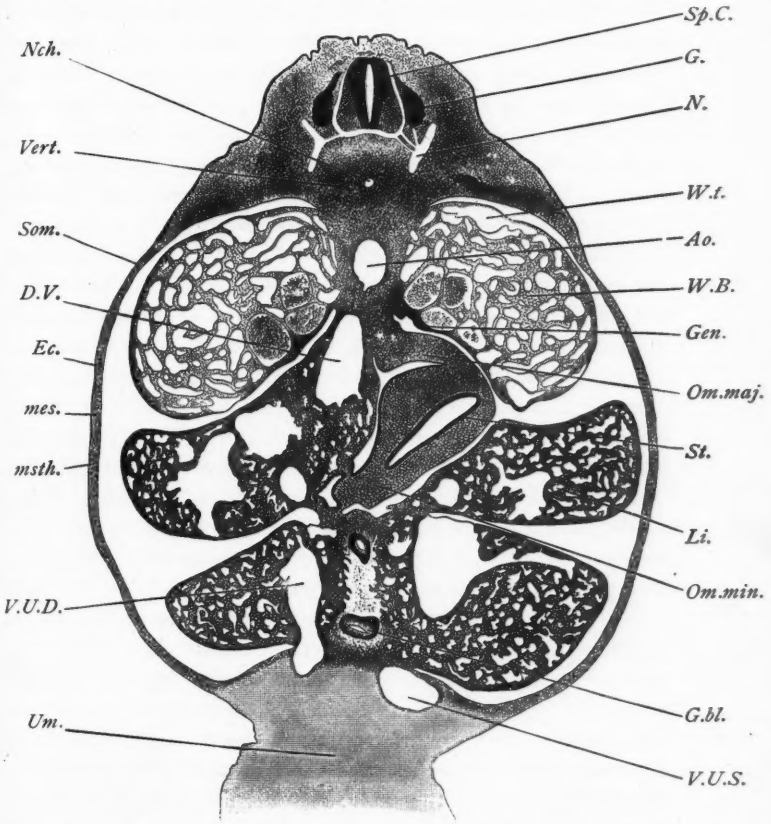


FIG. 7. — Pig of 12.0 mm. No. 5. Transverse section 633. *Ao.*, aorta; *D.V.*, ductus venosus; *Ec.*, ectoderm of the somatopleure; *G.*, ganglion on dorsal root of spinal nerve; *G.bl.*, gall bladder; *Gen.*, anlage of genital gland; *Li.*, liver; *mes.*, mesenchyma of somatopleure; *msth.*, mesothelium of the somatopleure; *Nch.*, notochord; *N.*, spinal nerve; *Om.maj.*, omentum major; *Om.min.*, omentum minus; *Som.*, somatopleure; *St.*, stomach; *Um.*, umbilical cord; *Vert.*, anlage of the body of a vertebra; *V.U.D.*, right umbilical vein; *V.U.S.*, left umbilical vein; *W.B.*, Wolffian body or mesonephros; *W.t.*, Wolffian tubule. × 22 diams.

formed by the union of the two dorsal aortic trunks of Fig. 6, and which extends through the abdominal region of the

embryo to the pelvis, where it forks to form the two allantoic arteries, which run to the umbilicus, and entering the umbilical cord supply the extra-embryonic or placental circulation. The aorta is surrounded by mesenchyma, and to this are, so to speak, appended the large Wolffian bodies (*W.B.*), one on each side. They are much larger, relatively to other parts, in the pig than in man or the rabbit. The Wolffian body is the fœtal or embryonic kidney, and is also termed the mesonephros. It consists of numerous epithelial tubules (*W.t.*), very much contorted, with blood spaces (sinusoids) between them, and of glomeruli, which always lie towards the median and inferior side of the organ. All of the tubules open into the single longitudinal canal, the Wolffian duct. This duct is always situated close to the surface on the ventral side of the organ, and is very easily distinguished in dissected embryos after the removal of the intestines and liver. In the figure it may be easily found in the left mesonephros (*W.B.*), it being there the lowermost of the cavities drawn. On the median lower surface of the Wolffian body, underneath the glomeruli, is an accumulation of tissue (*Gen.*), the anlage of the genital gland. Below the aorta, on the right of the embryo, is the large ductus venosus, or upper end of the vena cava inferior, on its way past the right dorsal lobe of the liver towards the heart. Below the aorta on the left is the mesogastrium (*Om.maj.*), or future great omentum, by which the stomach is suspended from the median dorsal wall of the abdomen. The stomach (*St.*) is entirely upon the left side of the body, and is directly connected by means of the anlage of the lesser omentum (*Om.min.*) with the liver. The liver is by far the largest organ of the body; it takes up nearly half of the section. It is divided into four main lobes, two dorsal and two ventral, two on the right and two on the left. The reference line (*Li.*) runs to the left dorsal lobe. The liver consists of a complicated network of relatively large blood sinusoids, the spaces between which are occupied by the embryonic liver cells. Near the median line between the ventral lobes appears the gall-bladder (*G.bl.*), which is cut three times. The liver is attached in the median ventral line to the body-wall

and the base of the umbilical cord. The two umbilical veins enter the liver directly from the cord. The right vein (*V.U.D.*) is already smaller than its left fellow (*V.U.S.*). They are connected respectively with the right and left ventral lobes of the liver. The right vein in a little later stage is no longer recognizable as an open channel. It will be noticed that the right and left sides of the abdominal cavity (splanchnocœle) are completely separated from one another, and that there is a special part of this cavity shown in the section between the stomach and the right dorsal lobe of the liver, and which is known as the lesser peritoneal space or cavity of the omentum. The body-wall (*Som.*), or somatopleure,[1] consists of three layers, — the ectoderm (*Ec.*), the mesenchyma (*mes.*), and the mesothelium (*msth.*). It is of the greatest importance for the student to understand the arrangement of the germ-layers in the somatopleure. The mesothelium (*msth.*) is commonly known in the descriptive anatomy of the adult as the peritoneal epithelium. In sections like that of Fig. 7 it can be followed not only over the inner surface of the body-wall but over the surface of the Wolffian body and liver, and upon the left side of the body also over the surfaces of the greater omentum, stomach, and lesser omentum. We see, in fact, that the body cavity is completely bounded by mesothelium, and that all the abdominal viscera are therefore outside of it. This conception, which is so important yet so difficult to the student of anatomy, is easily mastered by the study of the embryonic relations.

From the sagittal series of the same stage many instructive pictures are obtainable. I have selected a median section of the head, and one passing through the principal cephalic ganglia, for engraving, and give here the latter. The magnification is 22 diameters, the same as for the transverse sections Figs. 2 to 7. To the student of anatomy such a section as is shown in Fig. 8 is highly instructive, for it exhibits in a single picture many important fundamental relations of the cephalic nerves, particularly of the second, fifth, seventh,

[1] It is much to be regretted that German embryologists use the term "somatopleure" erroneously.

eighth, ninth, and tenth. As the section is remote from the median plane, little of the brain appears, there being only a shaving from the lateral wall of the fore-brain (*H.*) and a section of the widest part of the hind-brain, which shows the cavity or lateral recess (*R.L.*) of the fourth ventricle. The auditory vesicle or otocyst (*Ot.*) is cut; its narrow upward prolongation is the anlage of the ductus endolymphaticus. The otocyst lies in a line with the great cephalic ganglion, occupying its invariable and permanent position behind the acustico-facial ganglion (*Ac.F.*) and in front of the glossopharyngeal. Only the lateral portion of the pharynx (*Ph.*) appears; this portion forms a wide diverticulum, almost slit-like (compare Fig. 4), from which extend the first and second entodermal gill-pouches. In the figure the pharynx has a small depression extending downward at the œsophageal end of the part shown in the section; this depression marks the beginning of the second cleft. Nothing is seen of the third and fourth clefts in the section, as these both lie nearer the median plane. The pocket or diverticulum of the cervical sinus (compare Fig. 1) appears (*Cerv.S.*) near the ganglion nodosum (*G.noa'.*). It might be mistaken for a gill-cleft, but it is lined by ectoderm and its cavity can be easily traced through the series to the exterior. Cephalad from the sinus but close to it lies a small dark mass, the anlage of the thymus gland. The mass is produced by proliferation of the entodermal cells on the anterior side of the third cleft (compare Fig. 5, *Thm.*), and is penetrated by blood vessels which seem to be sinusoids, although their history has not been worked out. The jugular vein (*Jug.*), owing to its irregular course, is cut several times; its main stem (*Jug.''''*) rises nearly vertically through the cervical region, and is, relatively to the size of the embryo, of huge diameter, and continues (*Jug.'''*) upward along the dorsal side of the vagus nerve to a level about halfway between the ganglion nodosum and ganglion jugulare, and as the vessel there curves inwards and forwards it is not encountered again until it bends outwards (*Jug.'*) on its way past the trigeminal ganglion. A branch of the jugular vein (*Jug.''*) is cut just above the ganglion.

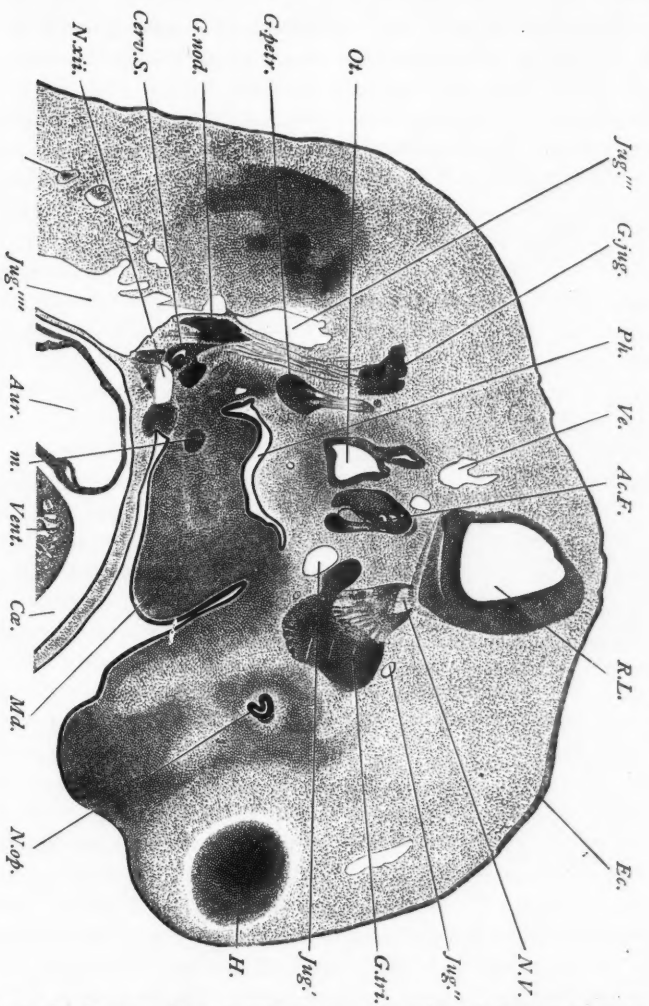


FIG. 8. — Pig of 12.0 mm. No. 7. Sagittal section 25. *Aur.*, auricle of the heart; *Ac.F.*, acusticofacial ganglion complex; *Cœ.*, cœlom around the heart or pericardial cavity; *Cerv.S.*, diverticulum of the cervical sinus, just in front of which shows the anlage of the thymus, which is deeply stained; *G.jug.*, ganglion jugulare of the vagus nerve; *G.nod.*, ganglion nodosum of the vagus nerve; *G.petr.*, ganglion petrosum of the glossopharyngeal nerve; *G.tri.*, ganglion of the trigeminus nerve; *H.*, lateral wall of the cerebral hemisphere; *Jug.*, jugular vein; *Jug.'*, behind the trigeminus; *Jug.''*, branch in front of the trigeminus; *Jug.'''*, main stem behind the vagus; *Jug.''''*, main stem descending to join the duct of Cuvier: *m.*, an undetermined structure, probably the anlage of a lingual muscle; *Md.*, mandible; *N.V.*, root of the fifth or trigeminal nerve; *N.op.*, optic nerve; *N.xii.*, twelfth or hypoglossal nerve; *Ot.*, otocyst; *Ph.*, pharynx; *R.L.*, recessus lateralis of the fourth ventricle; *Ve.*, small branch of the jugular vein; *Vent.*, ventricle of the heart. × 22 diams.

The nerves are shown as follows : The optic nerve (*N.op.*) still has its central cavity, which, nearer the median plane, opens into the third ventricle of the brain, and in the section resembles in shape an inverted U. On the side of the nerve towards the mouth there is a deep notch, — the section of the choroid fissure. The trigeminal ganglion (*G.tri.*) is very large, and its trilobate form is clearly indicated by the figure. The lobe to which the reference line (*G.tri.*) runs gives off the ramus ophthalmicus ; the lobe nearest the jugular gives off the ramus maxillaris inferior, while the middle lobe gives off the ramus maxillaris superior. From the ganglion the fibres and nerve cells extend upwards to form the root (*N.V.*), which joins the hind-brain at a characteristic point,— namely, at the summit of the Varolian bend and where the hind-brain is widest (compare Figs. 2 and 3). By its great size and by its topographical association with the lateral apex of the recessus lateralis of the fourth ventricle, the trigeminal ganglion may always be readily identified in sections of embryos. The acustico-facial ganglia (*Ac.F.*) may also be readily determined by their typical position immediately in front of the otocyst (*Ot.*). But it is quite difficult to identify the four components of this complex structure, namely : 1°, the motor root of the facial nerve ; 2°, the facial or geniculate ganglion ; 3°, the vestibular ganglion ; 4°, the cochlear ganglion. In Fig. 8 three divisions are shown. The large, darkly stained division, to which the reference line (*Ac.F.*) runs, and which lies nearest to the otocyst, is the vestibular portion of the acoustic ganglion ; the small, light area occupying a middle position in the inferior part of the complex is the motor division of the seventh nerve, or lateral root of the facial ; it can be followed to the brain, which it enters as four bundles of fibres ; its path of entrance is shown better in frontal sections (Fig. 10). Just in front of the facial motor root lies a second smaller dark mass, the geniculate ganglion of the facial, with an upward prolongation, the sensory root. The ninth or glossopharyngeal nerve is represented by the ganglion petrosum (*G.petr.*) and its ascending sensory root. This nerve may be quickly identified because it is the first behind the otocyst. The upper ganglion of this

nerve, the so-called Ehrenritter's ganglion, is represented by an accumulation of cells in the upper part of this root. As regards the tenth nerve, or vagus, both its ganglia and the fibrous trunk connecting them are shown. The upper or jugular ganglion (*G.jug.*) is nearly on a level with the otocyst, while the lower or nodosal (*G.nod.*) lies near the cervical sinus. To the nerve trunk between the two ganglia are adjoined the fibres of the eleventh or spinal accessory nerve, which does not otherwise appear in this section. A small piece only of the hypoglossal nerve can be seen (*N.xii.*). The space occupied by this nerve is blank in the engraving; in the specimen it shows horizontal fibres.

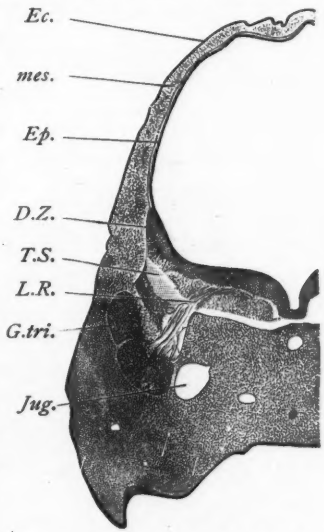


FIG. 9.—Pig of 12.0 mm. Series No. 6. Frontal section 284. *Ec.*, ectoderm; *Ep.*, ependymal roof of the fourth ventricle; *D.Z.*, upper portion of the dorsal zone of His; *G.tri.*, ganglion trigemini; *Jug.*, jugular vein; *L.R.*, lateral root of the trigeminal nerve; *mes.*, mesenchyma; *T.S.*, tractus solitarius of W. His. × 22 diams.

The frontal series has special value for the study of the hind-brain, its nerves, and of the otocyst. From this series I present here three figures of the head region. The first of these sections (Fig. 9) passes through the widest part of the hind-brain and through the roots of the trigeminus. The cavity of the hind-brain is enormously distended; it is bounded on the dorsal side only by a very thin layer of cells, the epithelial roof or ependyma (*Ep.*), which does not form part of the true nervous structures, although it passes into and is directly continuous with the dorsal zone (*D.Z.*) of the medulla oblongata, which is thus seen (also in Figs. 10, 11) to be only the thickened ventral wall of the neural tube, just as the ependyma is the attenuated dorsal wall. The trigeminal ganglion (*G.tri.*) is very large and sends its sensory fibres

upwards into the dorsal zone to form there the tractus solitarius (*T.S.*). Its motor or lateral root (*L.R.*) is below the ganglion and nearer the median line. As it enters the brain it curves and as a still distinct bundle runs towards the median plane. Its similarity to the motor root of the facial is very striking, but so far as I am aware has not been recorded hitherto (compare Figs. 9, 10). Inside of the trigeminal ganglion lies the jugular vein.

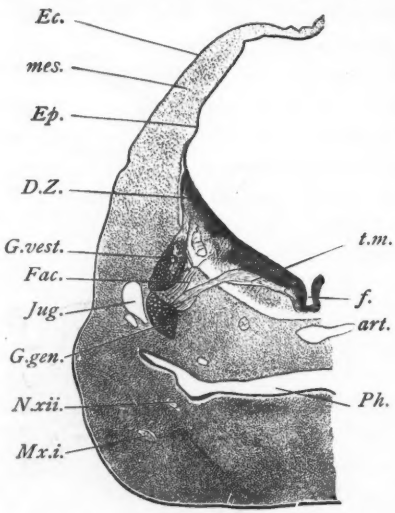


FIG. 10. — Pig of 12.0 mm. No. 6. Frontal section 340. *art.*, arteria basilaris; *D.Z.*, dorsal zone of the medulla oblongata; *Ec.*, ectoderm; *Ep.*, ependymal roof of the fourth ventricle; *f.*, median fissure of the medulla oblongata; *Fac.*, sensory root of the facial nerve; *G.gen.*, geniculate ganglion of the facial nerve; *G.vest.*, ganglion vestibuli of the acoustic nerve; *Jug.*, jugular vein; *mes.*, mesenchyma; *Mx.i.*, inferior maxillary branch of the trigeminal nerve; *N.xii.*, hypoglossal nerve; *Ph.*, pharynx; *t.m.*, motor tract of facial nerve. × 22 diams.

The next figure (Fig. 10), through the acustico-facial ganglion, shows the thickened ventral wall of the hindbrain (*i.e.*, the anlage of the medulla oblongata) no longer spread out nearly horizontally, but rising obliquely from the median line. The right and left sides of the medulla oblongata are divided from one another by a deep median fissure (*f.*). In the median line just below appears the basilar artery (*art.*), and still lower the wide, slit-like pharynx (*Ph.*), the outer portion of which ascends obliquely towards the jugular vein. The ascending part is a portion of the first gill-pouch (future Eustachian tube) and is quite clearly marked off from the pharynx proper. Of the acustico-facial complex the section shows four parts: the ganglion vestibuli (*G.vest.*); the geniculate ganglion (*G.gen.*); the sensory root (*Fac.*) of the facial nerve arising from the geniculate ganglion and entering the brain to form there a distinct

fibre tract, which is oval in section, lies just below the entering vestibular fibres, and is indicated in the engraving; finally, the motor tract (*t.m.*) of the facial; this tract is a very distinctly marked bundle of nerve fibres, which traverse the ventral zone of the medulla almost horizontally, then come downwards and, passing out from the brain-wall, form the *lateral* root of the facial; this root runs first towards and then past the geniculate ganglion. The jugular vein (*Jug.*) lies outside the ganglia, not inside, as in Fig. 9. In the mandible appear two nerves; of these the upper is the hypoglossal (*N.xii.*); it lies near the angle formed by the junction of the first gill-cleft with the pharynx proper; the lower is the inferior maxillary.

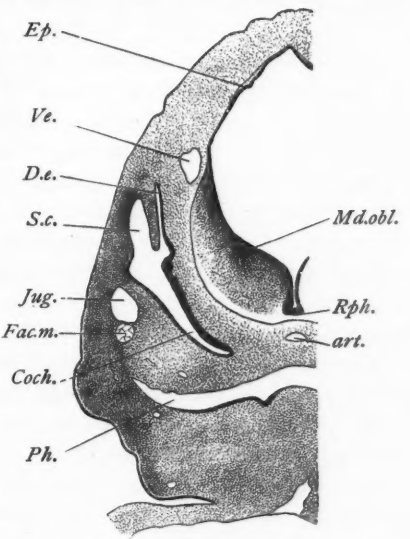


FIG. 11.—Pig embryo of 12.0 mm. No. 6. Frontal section 380. *art.*, artery; *Coch.*, cochlea; *D.e.*, ductus endolymphaticus; *Ep.*, ependyma; *Fac.m.*, motor division of the facial nerve; *Jug.*, jugular; *Md.obl.*, medulla oblongata; *Ph.*, pharynx; *Rph.*, median raphe of the medulla oblongata; *S.c.*, anlage of the semicircular canals; *Ve.*, vein. × 22 diams.

The next figure is from a section not far from the last and chosen to show the otocyst. The hind-brain has narrowed considerably; its thickened floor (*Md. obl.*), the anlage of the medulla oblongata, rises steeply from the median line; its ependymal roof (*Ep.*) is less expanded than in Figs. 9 and 10 and forms a sharp angle in the dorsal median line. The two sides of the medulla are separated by a deep fissure (*cf.* Fig. 10, *f.*), underneath which the wall of the brain is correspondingly thinned, constituting the floor plate (*Rph.*), which is transformed in the adult into the median raphe. The pharynx (*Ph.*) is wide and is expanded laterally into the common

beginning of the first and second gill-pouches. Between the pharynx and the raphe the basilar artery (*art.*) has been cut transversely. The otocyst is a large epithelial vesicle with three well-marked divisions: first, the common chamber (*S.c.*), out of which the three semicircular canals are to be differentiated; second, the slender canal (*D.e.*), the anlage of the ductus endolymphaticus, which lies between the semicircular canals and the medulla; third, the long, curving, but not spiral, cochlea (*Coch.*). The common chamber formed by the union of these three divisions is later subdivided to form the upper utriculus and lower sacculus. Outside the cochlea lies the cross-section of the jugular vein (*Jug.*), just below which is the section of the motor portion (*Fac.m.*) of the facial nerve. The sensory portion of the facial is much smaller, runs only a short distance downwards from the geniculate ganglion, and is entirely separate from the motor portion. It seems to me, therefore, that the anatomical description of this nerve, in view of the embryonic conditions, needs revision.

The absence of advanced stages of histological differentiation at this period of development is a general and characteristic state of the tissues. Especially noteworthy is the simple character of the mesenchyma, for it offers no marked differentiation except that of the merely endothelial blood vessels and their contained blood. The blood corpuscles are all nucleated red cells, which are for the most part in embryos of twelve millimeters, in a transitional stage. In younger pigs the corpuscles are in the ichthyopsidan stage and have a full-sized nucleus with quite distinct chromatin granules. In older pigs the corpuscles have much-contracted nuclei, which stain darkly, as in the blood cells of Sauropsida. In our embryo the nuclei are partly contracted and modified. The mesenchyma proper is very voluminous and constitutes a large proportion of the total bulk of the body. Its cells vary much in the degree in which they are crowded in the different territories of the tissue, and they vary also in form, but they can hardly be said to offer any positive specialization, and there is probably at this stage no differentiation of the fibrils and elastic networks, which are so conspicuous in many of the adult tissues which are derived

from the embryonic mesenchyma. The simplicity of mesenchymal structure is further emphasized by the absence of distinct layers. Thus, between the brain and the ectoderm there is a continuous layer of tissue nearly uniform in appearance; later, out of this layer there will have arisen the cutis, subcutaneous tissue, periosteum, bone, dura mater, arachnoid, and pia mater, while the complexity of organization will have been increased by the ingrowth of nerves and striated muscles. The entoderm and ectodermal epidermis are both quite simple epithelial structures, although the entoderm, it must be added, already presents some very important modifications, such as the notochord, the thymus and thyroid glands, and the liver. On the other hand, the neuro-ectoderm shows advanced differentiation of the neurones with their accompanying axons, from the neuroglia cells. The mesothelium also offers more complexity, owing to its share in the development of the striated muscles, of the Wolffian body, and of the genital glands.

The preceding illustrations and descriptions are published, partly in the hope that in spite of their fragmentary character they will prove useful to some students of mammalian embryology, partly in the hope that the author will receive from other teachers criticism and suggestions in regard to the proposed text-book.

HARVARD MEDICAL SCHOOL, BOSTON, MASS.
October 23, 1900.

ORIGIN OF THE MAMMALIA, III. OCCIPITAL CONDYLES OF REPTILIAN TRIPARTITE TYPE.[1]

HENRY FAIRFIELD OSBORN.

THE Huxleyan theory of the origin of Mammalia (Huxley, '80) from primitive Amphibia is still entertained by Howes ('87); it has recently been revived by Hubrecht ('97) upon the basis of the fœtal membranes, and by Kingsley ('99) upon the basis of the homology of the quadrate and upon other grounds. The position taken by the present writer ('98, '99) is that the weight of evidence favors the derivation of the Mammalia from some unknown member of the Anomodont reptiles (Theriodontia) of Permian or lower Triassic age.

One of Huxley's arguments for amphibian ancestry ('80) was that the paired exoccipital condyles of the mammals were derived from similar amphibian structures. This is cited by Kingsley. The object of the present paper is to show that the *mammalian occipital condyles arose from a reptilian tripartite type by the reduction of the median basioccipital element and the expansion of the lateral exoccipital elements.*

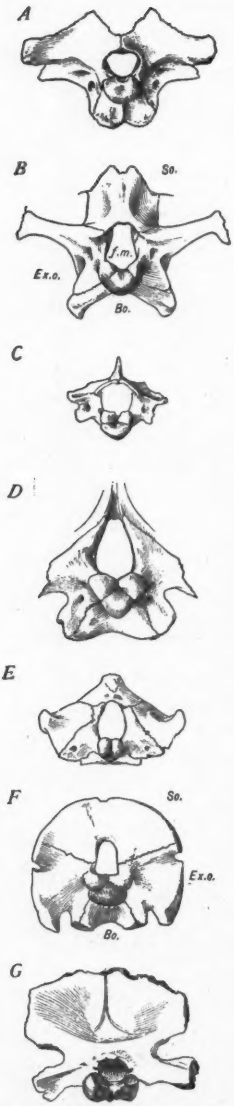
TYPES OF CONDYLES.

The terms "monocondylia" and "dicondylia" employed by Cope fail to express the facts, for the junction of the basal elements of the skull with the atlas vertebra is of four types, — I, II, III, IV, as follows:

I. *Monocondylic, Typical*

Single basioccipital condyle, exoccipitals not entering into articulation . . . . . Reptilia (*e.g.*, Alligator, Ichthyosaurus)

[1] Presented before Section of Zoölogy, American Association for the Advancement of Science, June, 1900. Contributions I and II upon the Origin of Mammals are cited in the bibliography.



II. *Monocondylic, Tripartite.*
Single condyle, basi- and exoccipitals in different proportions.
Reptilia (*e.g.*, Chelone, Fig. 1, *B*, *C*, *D*, *E*).

III. *Dicondylic, Transitional.*
Paired condyles, chiefly exoccipital, partly basioccipital.
Reptilia (*e.g.*, Cynognathus, certain Mammalia).

IV. *Dicondylic, Typical.*
Paired exoccipital condyles, basioccipital element cartilaginous or reduced in median line.
Amphibia (Rana, Mastodonsaurus) and certain Mammalia.

The above types are arranged morphologically, not genetically. Seeley ('88, p. 100) has pointed out the significance of the morphological transition from I to IV as consisting in the reduction of the basioccipital and enlargement of the exoccipital elements; he concludes: "Hence it is possible that the condylar cranial characters may be related in an evolutionary sequence of gradation, and that the change from one condition to another may be consequences of one plan of vertebrate organization rather than that of entirely independent plans."

The diagrams (Fig. 1) have been prepared to illustrate the transition between these types. They show that in the alligator the condyle is wholly basioccipital and below the foramen magnum. In the lizard, python, and two genera of Chelonia we observe a gradual expansion of the exoccipitals and reduction

FIG. 1. — Reptilian condyles. *A*, *Alligator lucius*; *B*, *Iguana tuberculata*; *C*, *Python reticulatus*; *D*, *Chelone midas*; *E*, *Testudo polyphemus*; *F*, Dicynodon (after Lydekker); *G*, Cynognathus (after Seeley). *A–D*, tripartite condyle, typical; *E–G*, reduction of basioccipital element. *Bo.*, basioccipital; *Ex.o.*, exoccipital; *f.m.*, foramen magnum; *So.*, supraoccipital.

of the basioccipital; other Chelonia are typically monocondylic. In like manner certain Anomodontia (Theriodontia) are typically monocondylic; others have a tripartite condyle as figured in Dicynodon (*F*); others again have a tripartite V-shaped condyle with the foramen magnum lying between the exoccipital portions; finally, in Cynognathus (*G*), we have two prominent convex condyles on the lower sides of the foramen magnum composed chiefly of the exoccipitals.

It is from the latter type, in our opinion, that the mammalian structure was probably derived.

But it is first necessary to demonstrate why the apparently obvious derivation of the mammalian from the amphibian condition is improbable.

We do not know the origin of the condyles in the Amphibia; all we know is that as soon as the occipital region becomes osseous, the most primitive amphibians show paired exoccipital condyles with a median cartilaginous or reduced basioccipital element; the reduction of the basioccipital is almost a class character. No Amphibia, so far as known to the writer, exhibit any participation of the basioccipital in the formation of the condyle.

On the contrary, many of the mammals show an extensive participation of the basioccipital in the formation of the condyles; in fact, some mammalian condylar types might

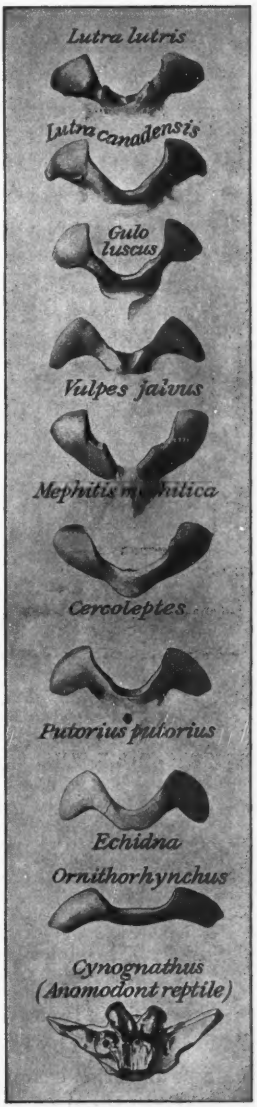


FIG. 2.—Mammalian condyles.

almost be termed tripartite. This gradation between a tripartite or transitional dicondylic condition and the "typical dicondylic" condition in the mammals is very clearly shown in the second series of diagrams (Fig. 2), which show these structures as seen from below or in palatal view.

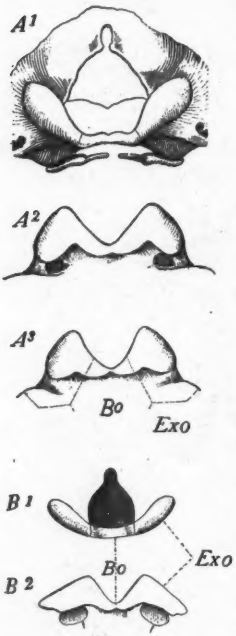


FIG. 3.—A^1–A^2, Echidna (Yale Museum, No. 300): A^1, from behind; A^2, from below; condyles joined by a broad cartilaginous bridge. A^3, Echidna (Yale Museum, No. 1691): from below; condylar surfaces barely separate. B^1–B^2, Ornithorhynchus: condylar ridges continuous; the cartilages are just separate when viewed from behind.

I am indebted to Mr. B. Arthur Bensley, Fellow in Zoölogy, Columbia University, for examining a large series of skulls in the American and Yale Museums (7 Monotremata, 12 Marsupialia, 15 Rodentia, 12 Carnivora, 7 Insectivora, 3 Cheiroptera, 4 Lemuroidea, 3 Anthropoidea, 3 Artiodactyla), with the following results:

Monotremata: The thickness of the basioccipital plates is a conspicuous feature of all monotreme skulls. (Yale Museum, Nos. 244, 300.) In three skulls of Echidna the exoccipital condyles are joined by a broad cartilaginous (basioccipital) bridge, very conspicuous after soaking in water (Fig. 3, A^1, A^2); in two skulls the condyles are joined by a narrow ridge; in two others (A^3) the condylar ridges are discontinuous. In Ornithorhynchus there is little variation in the condylar region (Fig. 3, B^1, B^2); the condylar ridge is continuous across the basioccipital region, the articular cartilages being slightly separate only when viewed from below. So far as this positive evidence goes, it is confirmatory of the theory of tripartite origin.

Marsupialia: The exoccipital condyles are distinct and separate in all forms examined except in Dasyurus, where there is a slight tendency to bridge the basioccipital (*D. maculatus*); this negative result is in keeping with the writer's theory of the *non-primitive* character of the marsupials.

Rodentia: The types examined give negative results.

Carnivora: A more or less distinctly tripartite condition is very common; Lynx, Mephitis, Taxidea, Lutra, Gulo, Putorius, Bassaris (Fig. 2) show all gradations in the participation of the basioccipital.

The conclusions are: (1), unlike reptiles, in no mammal does the basioccipital project backwards as far as the exoccipitals; (2), nevertheless the participation of the basioccipital in the condylar articulation is a common feature, and the monotremes present some grounds for considering it a primitive mammalian feature; (3), the weight of evidence is in favor of derivation from a tripartite type with a depressed basioccipital.

The evolution and gradation of the condyles in the Anomodontia (Theriodontia), from a typically monocondylic to a transitional dicondylic condition, in conformity with other mammalian structures in this order, tend to connect them with the hypothetical ancestral forms of mammals. Taken in connection also with the conditions we have been pointing out among living types, the reptilian tripartite origin of the mammalian condyles is rendered more probable than the amphibian dicondylic origin.

July 20, 1900.

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CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. No. 117.

STUDIES ON THE CAUSE OF THE ACCELERATING EFFECT OF HEAT UPON GROWTH.

T. W. GALLOWAY.

THE following studies, directed toward a further analysis of the fact that the rate of growth of organisms varies with temperature, were made at the suggestion and with the guidance of Dr. C. B. Davenport. Growth, defined as increase in volume or mass, is evidently produced by one or both of the following processes: either (1) by imbibition of water, which results in an increase of cell sap, or (2) by assimilation, *i.e.*, anabolic metabolism, which results in the increase of plasma and of formed substance, such as starch, cellulose, etc. The question to which an answer was sought is this: In the acceleration of growth due to higher temperature, are imbibition of water and anabolic metabolism equally accelerated? or, if unequally affected, in which process is acceleration most marked?

The procedure embraced the following points:

1. Experiments were made upon the larvæ of *Rana sylvestris*, *Amblystoma punctatum*, and *Bufo americana*.

2. Fertilized eggs of a single spawning were subjected to three different temperature conditions: (1) 6°–8° C., (2) 12°–18° C. (12°–15° C. in Rana), and (3) 22°–25° C. (20°–24° C. in Amblystoma). The other conditions were as nearly as possible alike in the three cases.

3. No food was supplied other than that contained in the egg and in the albumen surrounding the embryo; consequently, these results apply only to the early stages of development in the amphibian embryo.

TABLE I. — RANA SYLVESTRIS.

DATE.	No. of Days.	Length. mm.	Average Weight. mg.	Av. Wt. Dry Substance. mg.	Average Weight Water. mg.	Per cent of Dry to Whole Weight.
1. TEMPERATURE 6°–8° C.						
March 23[1] . . .	—	—	3.98	1.50	2.48	37.5
April 5	13	5	4.46	1.49	2.97	33.4
" 8	16	6	5.04	1.58	3.46	31.3
" 11	19	7.5	6.12	1.64	4.48	26.8
" 16	24	10	8.26	1.58	6.68	19.1
" 19	27	10	9.50	1.54	7.96	16.2
" 22	30	10.7	10.12	1.50	8.62	14.8
" 27	35	11.2	13.30	1.44	11.86	10.9
" 29	37	12	12.70	1.40	11.30	11
May 3	41	12.2	19.10	1.44	17.66	7.5
" 5	43	12.2	19.38	1.44	17.94	7.4
" 12	50	13.5	21.02	1.52	19.50	7.2
2. TEMPERATURE 12°–15° C.						
March 23[1] . . .	—	—	3.98	1.50	2.48	37.5
" 29	6	7	6.66	1.62	5.04	24.3
" 30	7	8	7.06	1.50	5.56	21
April 1	9	10.5	10.49	1.51	8.98	14.3
" 4	12	12.5	18.32	1.46	16.86	8
" 6	14	13.5	22.60	1.30	21.30	5.7
" 8	16	14.5	28.18	1.78	26.40	6
" 12	20	16	36.30	1.70	34.60	4.7
" 16	24	16.5	37.96	1.82	36.14	4.7
" 20	28	17	39.82	1.98	37.84	4.4
" 22	30	17	33.50	1.76	31.74	5.2
3. TEMPERATURE 22°–25° C.						
March 23[1] . . .	—	—	3.98	1.50	2.48	37.5
" 25	2	11	5.29	1.30	3.99	24.6
" 29	6	19	18.01	1.18	16.83	6.5
April 1	9	—	24.56	1.25	23.31	5.1
4. INDIVIDUALS OF SAME SPAWNING TAKEN FROM 2 (SEE "MARCH 30" ABOVE), AND PLACED IN 3, AFTER THEY HAD BEEN IN AQUARIUM 7 DAYS.						
March 30	7	8	7.06	1.50	5.56	21
" 31	8	11	10.28	1.32	8.86	12.8
April 1	9	13	17.10	1.30	15.60	8.8
" 4	12	14	25.23	1.43	24.80	5.7
" 6	14	14.5	35.62	1.42	34.10	4
" 8	16	14.5	36.02	1.41	34.61	3.9
" 12	20	14.5	32.16	1.35	30.81	4.2

[1] Weight of embryo free of albumen, at beginning of experiment, several days before hatching.

4. The measurements taken were: (1) maximum length, (2) total weight when freed of superficial water, and (3) dry weight, obtained by desiccating the animals in an air-tight chamber containing sulphuric acid until they ceased to lose

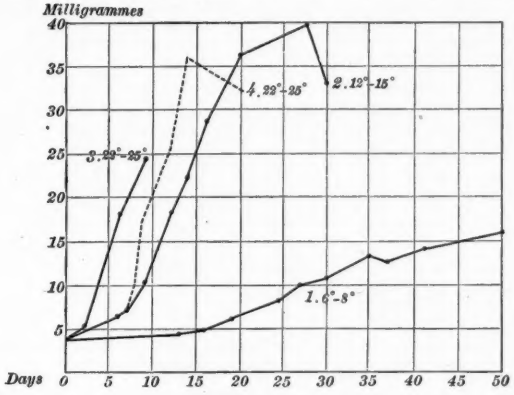


FIG. 1. — Rana. Graphic representation of Table I, column 4, showing average total weight on successive days of the experiment.

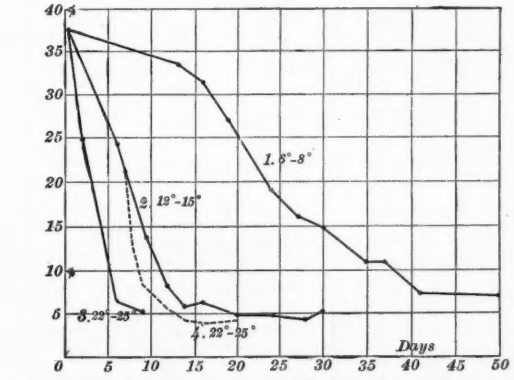


FIG. 2. — Rana. Graphic representation of the ratio of dry substance to the total weight. (See Table I, column 7.)

weight. From these were derived the amount of water present and the percentage of dry substance.

5. *Five* individuals were taken at random in determining all the averages recorded in this paper, except in the later

TABLE II. — AMBLYSTOMA PUNCTATUM.

DATE.	No. of Days.	Length. mm.	Average Weight. mg.	Av. Wt. Dry Substance. mg.	Average Weight Water. mg.	Per cent Dry Substance.
1. TEMPERATURE 6°–8° C.						
April 12	—	—	—	—	—	—
" 22	10	7.5	6.82	3.02	3.80	44.2
" 27	15	8.5	8.62	2.92	5.70	33.8
May 7	25	10	9.54	2.58	6.95	27
" 17	35	12	13.70	2.70	11.00	19.7
" 24	42	13	16.22	2.70	13.52	16.6
" 26	44	13.5	17.46	2.68	14.58	15.3
June 2	51	14	19.20	2.66	16.54	13.8
" 6	55	14.5	23.80	2.64	21.16	11.1
" 10	59	15	25.82	2.46	23.36	9.5
" 20	69	16	29.64	2.24	27.40	7.5
2. TEMPERATURE 12°–18° C.						
April 12	—	—	—	—	—	—
" 20	8	9	9.94	2.90	7.04	29.1
" 27	15	12	12.26	2.74	9.52	22.3
" 29	17	13	15.00	2.84	12.16	18.9
May 3	21	14	18.52	2.64	15.88	14.2
" 7	25	15	22.92	1.88	21.04	8.2
" 17	35	16.5	28.40	2.32	26.08	8.1
" 20	38	16	24.08	1.88	22.20	7.8
" 24	42	17	26.70	2.02	24.68	7.6
" 28	46	17	23.60	1.50	22.10	6.3
3. TEMPERATURE 20°–24° C.						
April 12	—	—	—	—	—	—
" 16	4	8.5	8.79	2.69	6.10	30.6
" 20	8	10.5	9.78	2.68	7.10	27
" 22	10	12	12.20	2.59	9.61	21.2
" 25	13	14	14.64	2.78	11.86	19
" 29	17	14	21.84	2.58	19.26	11.8
May 3	21	14.7	23.94	2.22	21.72	9.2
" 7	25	15	22.78	2.54	20.24	11.1
" 16[1]	34	14.5	17.80	1.86	15.94	10.4
" 20[1]	38	14.5	17.00	1.20	15.80	7

[1] Good many dying; evidently not thriving.

measurements of Bufo at the highest temperature; in this latter case *three* were taken.

Results. — The results are embodied in the accompanying tables and in the curves (Figs. 1–6) constructed from them.

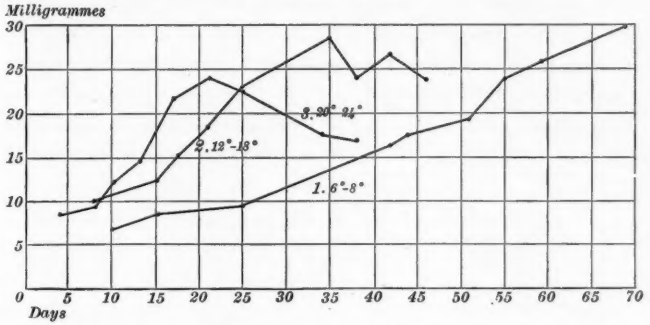


FIG. 3. — Amblystoma. Graphic representation of Table II, column 4, showing average total weight on successive days of the experiment.

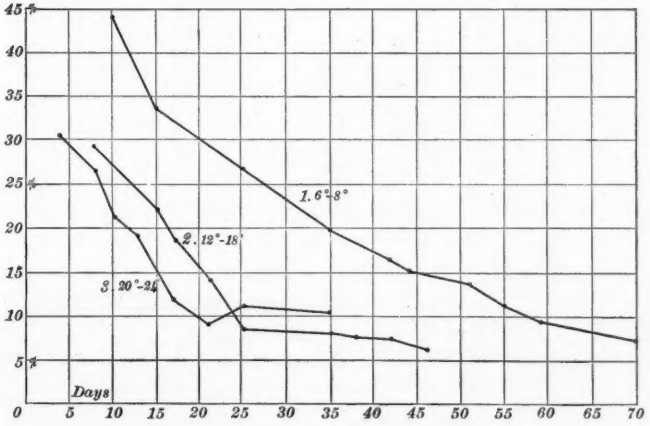


FIG. 4. — Amblystoma. Graphic representation of the ratio of dry substance to the total weight. (See Table II, column 7.)

The column headed "No. of Days" indicates the number of days reckoned from the beginning of the experiment, — not from hatching. The exact date of fertilization is unknown.

In Table I it will be seen that there are two sets of observations

recorded for the highest temperature. Owing to great acceleration and high rate of mortality, the first series (I; 3) was very short. To supplement this record I took some embryos of the same spawning, which had been for seven days in the aquarium, at a temperature of 12°–15° C., and placed them in the warm chamber (I; 4).

An accident prevented my getting a record for Bufo at the lowest temperature (6°–8° C.).

Conclusions. — 1. All the processes involved in the early development of these larvæ are accelerated by an increase of

TABLE III. — BUFO AMERICANUS.

DATE.	No. of Days.	Length. mm.	Average Weight. mg.	Av. Wt. Dry Substance. mg.	Average Weight Water. mg.	Per cent Dry Substance.
1. TEMPERATURE 12°–18° C.						
April 26	—	—	—	—	—	—
May 3	7	4.8	3.00	.82	2.18	27.3
" 5	9	6	3.36	1.02	2.34	30
" 7	11	7.5	5.98	.98	5.00	16.3
" 17	21	10.5	12.68	.84	11.84	6.6
" 20	24	10.5	11.00	.70	10.30	6.4
" 24	28	10.8	12.00	.64	11.36	5.3
" 28	32	10.5	12.08	.51	11.57	4.2
" 31	35	10.5	11.62	.60	11.02	5.1
2. TEMPERATURE 22°–25° C.						
April 26	—	—	—	—	—	—
" 30	4	5	2.50	.86	1.64	34.4
May 2	6	8	4.40	.94	3.46	21.4
" 3	7	10	9.54	1.10	8.44	11.5
" 5	9	11	15.96	1.00	14.96	6.6
" 7	11	13	21.00	.96	20.04	4.6
" 9	13	13	21.44	.92	20.52	4.3
" 10	14	13	22.12	.90	21.32	4
" 17	21	13	20.82	1.01	19.81	4.8

temperature within the limits used: + 6° to + 25° C. This is true of the early cell divisions preliminary to hatching, as

well as of the beginning and ending of the period of rapid imbibition of water.

2. Under the conditions of the experiment, the absolute dry weight appears to undergo little change. There is apparently a slight loss from the beginning of the experiment to the period of maximum percentage of water in the embryo. In studying the data I do not find any constant relation between this decrement and the temperature. Inasmuch as the prevailing difference in dry weight is so slight, it seems probable that the sudden fluctuations of weight seen in some of the measurements may be due partly to individual variation in the amount of food taken and in the presence of fæcal matter in the digestive tract, and partly to errors in weighing, which may amount to as much as 0.5 milligram. In some of the smaller weighings this would mean a possible error of 20%. Of course the *probable* error is much less than this. It appears safe to say that during the period embraced in my experiments, — from hatching until the attainment of the maximum percentage of water, — the dry weight is *unaffected* by temperature. It follows, therefore, that the acceleration and retardation experienced at this period in the growth of the larvæ by reason of different temperature conditions is due almost entirely to the changed rate of imbibition of water.

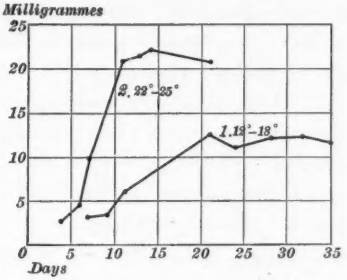


FIG. 5. — Bufo. Graphic representation of Table III, column 4, showing average total weight on successive days of experiment.

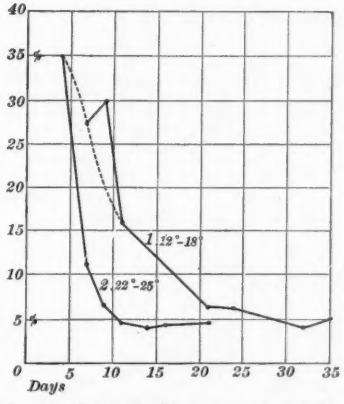


FIG. 6. — Bufo. Graphic representation of the ratio of dry substance to the total weight. (See Table III, column 7.) The broken line indicates the probable position of the curve; the second measurement is doubtless inaccurate.

3. The measurements of Rana also show that there was no appreciable gain in the dry weight of the egg, with the albumen removed, *up to the time of hatching.* There was during the same time a slight increase of water. Thus it appears that a part of the acceleration — by increased temperature — of the cell multiplications leading up to hatching may be due to the earlier inauguration of the imbibitory process.

4. The developmental process up to the point where the water amounts to 75% of the whole weight is not retarded so much by lowered temperature as is the stage representing the *maximum* percentage of water (see Table IV). In the first stage assimilation of yolk and cell division is prominent; in the latter imbibition of water is the main process. The

TABLE IV. — DESIGNED TO SHOW RELATIVE RETARDATION OF AN EARLY AND A LATER EVENT IN THE LARVAL DEVELOPMENT, PRODUCED BY LOWER TEMPERATURES.

	1. TIME IN DAYS REQUIRED TO ATTAIN 75% OF WATER; *i.e.*, 25% DRY SUBSTANCE.			2. TIME IN DAYS REQUIRED TO ATTAIN MAXIMUM PERCENTAGE OF WATER.		
	Highest Temperature.	*Medium Temperature.*	*Lowest Temperature.*	*Highest Temperature.*	*Medium Temperature.*	*Lowest Temperature.*
Rana	2	5.7	20	5	28	50 +
Amblystoma	9	12	27	21	50 +	70 +
Bufo	5.5	7.5	—	14	32	—
Average	5.5	8.4	23.5	13.3	36.6	60 + [1]
Retardation in days, reckoned from time required by highest temperature	—	2.9	18	—	23.3	46.6 +
Retardation in per cent	—	53%	327%	—	175%	350% [1]

[1] This result is certainly too small, since the length of time consumed in my observations did not suffice to reach the minimum percentage of dry substance in the lowest temperature conditions.

conclusion reached above (2), *viz.*, that it is chiefly the imbibitory process which is accelerated by heat, is thus further strengthened.

5. Organisms reared in the warmer conditions tend to attain a maximum percentage of water *slightly higher* than that reached by those reared at a lower temperature. This fact accentuates the conclusion reached in 4, in that a shorter time is required to accomplish a greater result.

6. On the other hand, it appears (see Figs. 1 and 3) that the lower temperatures allow the attainment of a somewhat greater *maximum total weight*, no extraneous food being supplied. The significance of this is not apparent. It is possibly due to the albuminous food material in the egg envelope being better preserved, and hence more completely available as food after hatching, than at the higher temperatures.

7. Finally, the individuals which were subjected for seven days to a temperature of 12°–15° and were then placed in a warm chamber, showed a greater rate of increase of imbibition water than those reared in the warm chamber from the beginning (Figs. 1 and 2). This indicates a tendency compensatory for early unfavorable circumstances, — an instance of the well-known regulative capacity of organisms.

ON THE VARIATION OF THE STATOBLASTS OF PECTINATELLA MAGNIFICA FROM LAKE MICHIGAN, AT CHICAGO.

C. B. DAVENPORT.

THIS study is concerned with the hooks on the statoblasts of one of our common fresh-water Bryozoa — *Pectinatella magnifica* Leidy — taken in August, 1898, from the Jackson Park lagoon, Chicago, connected with Lake Michigan.

Pectinatella is a genus comprising two known species: Magnifica, found in the United States west of the Rocky Mountains, and elsewhere reported only from Hamburg, whither it has doubtless been imported; and Gelatinosa Oka, from Japan.[1] The most striking peculiarity of the genus is the close association of many colonies, which, by secreting together a gelatinous base, come to lie on the surface of a great globular gelatinous mass. One is inclined to think at first that the whole mass must have been produced by the activity of a single colony; but it is certain that it is due to the activity of a number of independent but associated colonies. The separate colonies are, however, probably all derived from a single statoblast, the descendant colony of which has repeatedly divided to produce the colony complex. Consequently, all the associated colonies are closely related; this has an important bearing on our results.

The statoblasts are formed inside of the colonies and frequently in large numbers. In twenty-seven colonies, in which all fully formed statoblasts were counted, the maximum number obtained was forty-six, the minimum was four; and the mode was at twenty to twenty-four. As all colonies contained

[1] A possible third species of this genus has been named by Hyatt ('66–'68) *Pectinatella Carteri*, from a single statoblast described by Carter ('59), remarkable for its hooks, which grow only at the ends of the statoblast and which are furnished with many lateral claws.

developing, still immature statoblasts, these numbers would have been greater later in the season.

The statoblast consists of a central, nearly circular, disk surrounded by a narrow, ring-shaped float. Placed radially at the margin of the statoblast are a varying number of hooks; the variability of this number was the starting point of the present investigation.

The statoblasts counted were found partly floating free in the preserving fluid and were partly picked out of the colonies, those from one colony being carefully kept together; 827 statoblasts were counted altogether, of which 635 came from known colonies.

Results. — The results of countings made on all statoblasts and on statoblasts from known colonies only is as follows:

Classes.	All Statoblasts.	Statoblasts from Colonies only.	Classes.	All Statoblasts.	Statoblasts from Colonies only.
11	11	7	17	23	18
12	106	79	18	2	1
13	265	201	19	2	2
14	238	186	20	0	0
15	122	93	21	1	1
16	57	47			

The quantitative study of these seriations gives the following constants:

	All Statoblasts.	Statoblasts from Colonies only.
n	827	635
M	13	13
A	$13.782 \pm .031$	$13.814 \pm .036$
ϵ	$1.318 \pm .022$	$1.326 \pm .026$
c	$9.57 \pm .16$	$9.60 \pm .19$
	$F = -1.758$	
	Type IV	
	Asymmetry $= +0.0766$	

Conclusions. — Since the results based on "all statoblasts" and on "statoblasts from colonies" differ by less than their

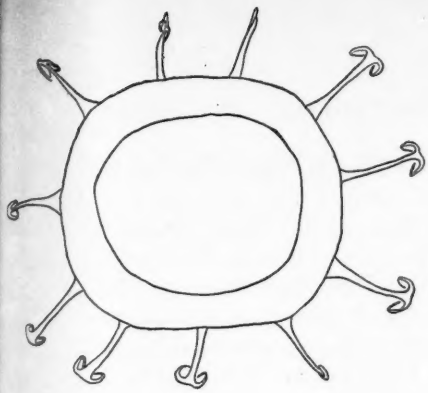
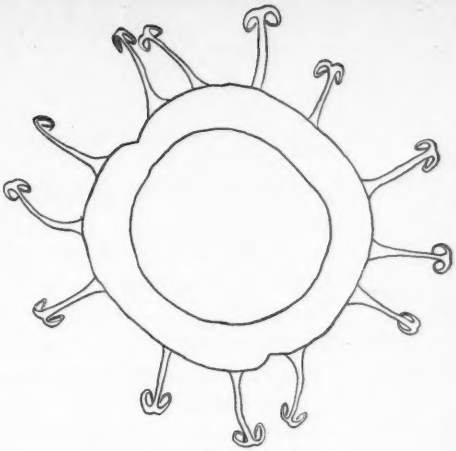


FIG. 1.



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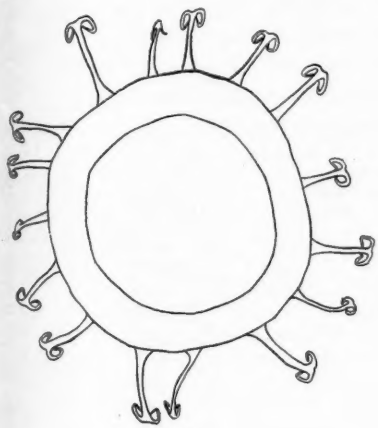

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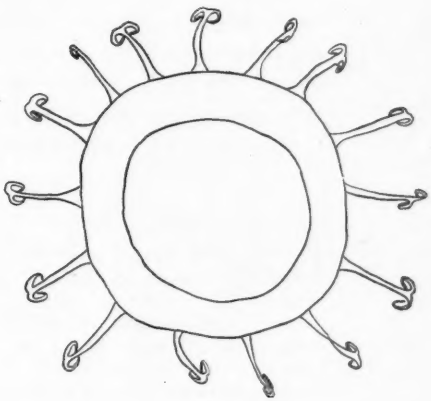

FIG. 4.

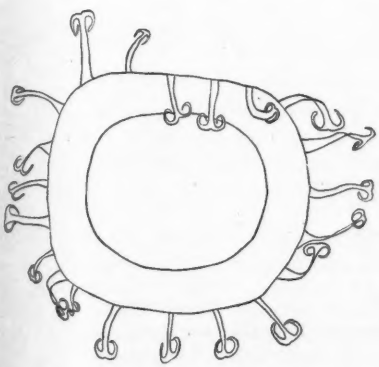

FIG. 5.

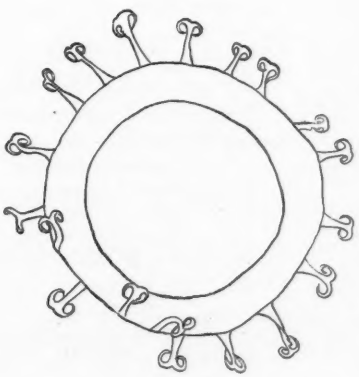

FIG. 6.

FIGS. 1-6. — Outline camera drawings of statoblasts of Pectinatella showing variation in the number of hooks. 1. 11 hooks. 2. 13 hooks. 3. 15 hooks. 4. 16 hooks. 5. 18 hooks. 6. 21 hooks. Compare the length of the hooks in Figs. 1 and 5. × 45.

probable errors, we need discuss only the larger collection of 827 statoblasts.

The mode is 13, the range from 11 to 21; or, omitting the single statoblast with 21 hooks, the range is 11–19 (Figs. 1–6). Statoblasts from Fresh Pond, Cambridge, Mass., are stated by Hyatt to have had, in 1866, 12–17 hooks; and those of Pennissewassee Pond, Maine, 20–22 hooks. The statoblasts of *Pectinatella magnifica* which Kraepelin found at Hamburg varied like those at Fresh Pond, 12–17.

The mode lies over toward the lower limit of the range; consequently the mean lies above the mode and the skewness is rather large, + 0.077.[1] The index of variation (ϵ) is rather large as compared with that of other integral variates. The coefficient of variation (c) is also large as compared with that derived from some graduated variates, as the following series shows:

ORGAN.	INDEX OF VARIATION.	MEAN.	COEFFICIENT OF VARIATION.
Rays of dorsal fin, Acernia	[2]0.6040	14.16	4.266
Müllerian glands of swine	1.6808	3.50	48.009
Rostral teeth *Palæmonetes varians* . .	0.8627	4.31	19.999
Height of U. S. recruits	2.5848 in.	67.30 in.	8.689
Height of St. Louis schoolgirls, aged 8	5.5524 cm.	118.27 cm.	4.698
Length-breadth index, Bavarian skulls	3.468 mm.	83.07 mm.	8.621
Length right human ♂ femur	23.72 mm.	452.28 mm.	5.425
Length right radius human ♀ radius .	10.95 mm.	214.86 mm.	5.096
Angle of neck of femur with shaft . .	5.578°	124.26°	4.469
Maximum length of clavicle ♀	9.208 mm.	136.85 mm.	6.724
Sacral index ♂	9.353%	115.000%	8.137
Scapular index	3.815%	65.900%	8.575
Infra spinous index of scapula	8.572%	89.454%	9.893

[1] For comparison I introduce some skewness determinations of other qualities:

Pearson, '95, Weldon's crab measurements, "No. 4" . . .	+ .077
" " Baxter's height of 25,875 recruits, U. S.	− .038
" " Porter's height of 2192 St. Louis schoolgirls . .	− .049
" " 900 Bavarian skulls: length-breadth index . . .	+ .032
" " dorsal teeth of *Palæmonetes varians*	+ .130
Pearson & Filon, '98, Müllerian glands of swine	+ .311
Rays of Pecten, lower valve	+ 0.023
" " " upper "	+ 0.000000058

[2] The first three data are derived from counting. They are integral variates. In them we see that the index of variation is more constant than the coefficient

The curve is of Type IV, or has unlimited range, like most biological curves. The skewness of the distribution indicates possibly a selective weeding out of statoblasts with a small number of hooks. Such a result is not unlikely, for (within certain limits) we might expect statoblasts with a larger number of hooks to have a better chance of keeping their hold and forming new colonies than those with fewer hooks. On the

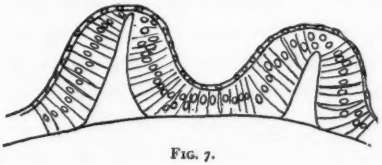

FIG. 7.

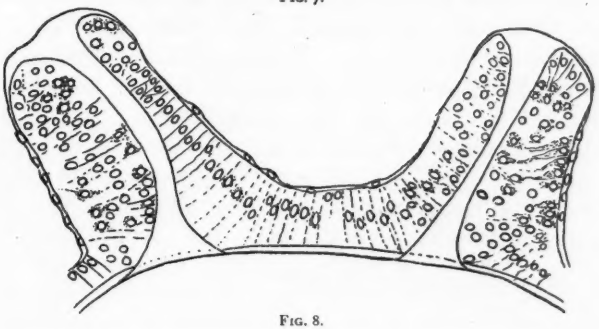

FIG. 8.

FIG. 7. — Early stage in formation of hooks. Section taken in the plane of the float and at its outer margin. ×

FIG. 8. — Later stage in formation of hooks. Section taken as in Fig. 7. × ca. 400.

other hand, the skewness may mean a tendency of the species to give rise to races with a larger modal number of hooks than 13. Such a race has been formed in Maine (Hyatt); and in *P. gelatinosa* the number of hooks is said to be "great" (Oka).

We have next to consider the question whether there is an hereditary tendency to produce a certain constant number of

of variation, and it is doubtless to be preferred to the coefficient. In the remaining cases, which are graduated variates, the coefficients are the more constant, varying from 4 to 9, whereas the indices vary from 2 to 23. Doubtless here the coefficient is to be preferred; moreover it is an abstract number, so that the results are comparable, whether millimeters, inches, degrees, or percentages are employed as units of measurement.

hooks in the same colony; or, in other words, whether the variability in the number of hooks found on statoblasts of the same colony will be less than the variability of the statoblasts from all the colonies taken together. To answer this question, I selected the eleven colonies showing the greatest number of statoblasts, and determined for each colony the ϵ and the c. Then I averaged the ϵ's and the c's for the eleven colonies, and compared these averages with the ϵ and the c of the 635 statoblasts coming from known colonies considered together. If the average ϵ or c of statoblasts from the same colony is no less than the ϵ or c of the population at large, there is no heredity. If, on the other hand, the ϵ's and c's of the colonies average zero, so that the differences between the variability inside the colony and in the whole population is the greatest possible, then there is the strongest possible heredity. In general, the percentage which the difference between the averaged ϵ or c is of the ϵ or c of the whole population, subtracted from unity, will serve as an index of heredity. I find:

	ϵ	c
Average for 11 colonies,	1.197	8.772
All statoblasts from colonies,	1.326	9.597

Index of relative heredity based on ϵ, $1 - \frac{1.197}{1.326} = 1 - 0.9027 = .0973.$

" " " " " " c, $1 - \frac{8.772}{9.597} = 1 - .9140 = .0860.$

The hereditary tendencies inside the colony are thus seen not to be very strong when compared with the tendency to similarity between all the statoblasts of the complex of colonies. I interpret this to mean that there is a close relationship between all the colonies in the complex.

The question next arose, what is the ontogenetic explanation of this variation?

To get some light on this matter, I studied the method of development of the hooks. As already stated, the hooks arise at or near the outer margin of the ring-shaped float; there is a little variation in the line of origin. Even after the float has been formed, the statoblast is clad externally with cells. Those at the outer edge of the statoblast are narrow and elongated

perpendicularly to the surface of the statoblast. Between the cells are large water spaces, which may indicate that the hook-forming layer is turgescent, at least at the time of forming hooks.

The first step in the formation of a hook is a fold (Fig. 7). As many folds arise at about the same time as there are hooks. Consequently the number of hooks is determined by the number of folds, and the question of the cause of variability is transferred to the folds. I had thought at first that each fold might be derived from one cell, but since the hook-forming layer spreads over the forming float and consists already of numerous columnar cells, it would be difficult, if not impossible, to demonstrate this if it were so. The forming papilla is made up of 100 to 200 cells at its beginning. In its center is a core, filled with a secretion, which hardens to form the shaft of the hook. The prongs are secreted as a superficial cuticula at the apex of the papilla (Fig. 8). From this it will be seen that my hypothesis was incorrect, and I find in the embryology no ground for referring the number of hooks to a predetermining number of hook-forming Anlagen.

It is possible that the number of papillæ may be correlated with a variation in the perimeter of the statoblast, so that the number of hooks per unit of perimeter is constant. To settle this question, I measured the perimeter[1] of 125 statoblasts. I found these measurements interesting in themselves. The modal perimeter of the statoblasts was about 3.3 mm. The average was 3.319 ; $\sigma = .06649$ mm. ; and $c = 2.00$, a remarkably low variability, almost one-fifth that of the number of hooks. By the use of the Galton-Pearson-Duncker[2] method of calculating

[1] The perimeter was measured by finding the length of a camera outline by means of the map-measure described in my *Statistical Methods* (New York, John Wiley & Sons, 1899).

[2] The reviewer of my *Statistical Methods*, in *Nature*, Dec. 14, 1899, says : " On p. 33 we notice a lengthy method, quoted from Duncker, given for reducing the product sum ; this should be replaced by the ordinary straightforward process of reduction to the mean." Although I have been satisfied of the correctness of Duncker's formula, which is got from Pearson's by a process of simplification, I calculated r by Pearson's method. Using logarithms, this took about four hours ; whereas to calculate r by Duncker's method took in this case about twenty minutes. The results differed by .001. The length of Pearson's process is a great obstacle to its use.

correlation, I found the correlation between the number of hooks and the length of the periphery of the statoblast to be $r = -.0920 \pm .0055$, a very low correlation, but slightly negative. I give the correlation surface :

X_2	X_1	11	12	13	14	15	16	17	18	19
255–59.9	1					1				
260–64.9	2				1					
265–69.9	3			3	2	1				
270–74.9	4		5	14	12	7	4			1
275–79.9	5		1	18	6	2	5	1	0	1
280–84.9	6	1	3	15	6	4	3			
285–89.9	7			3	0	0	1			

$$X_1 \begin{cases} A = 13.8264. \\ \epsilon = 1.3403. \end{cases} \qquad X_2 \begin{cases} A = 4.8182. \\ \sigma = 1.0499. \end{cases}$$

The negative correlation between length of periphery and number of hooks signifies that in the long run small statoblasts tend to have slightly more hooks than large statoblasts, a result which we should hardly have anticipated. The result makes it clear that the number of hooks which shall develop is not determined by the space at their command for development. In a statoblast with eleven hooks, these are twice as far apart as in a statoblast with twenty-one hooks. The ontogenetic cause of the variation in number of folds remains thus still undetermined.

Although the *number* of hooks is not directly correlated with the periphery of the statoblast, it is rather strongly correlated with the *length* of the hooks ; and the correlation is inverse. This is quite striking from superficial observation. To express the relation in a roughly quantitative way, I measured a representative lot of the hooks on each of ten statoblasts. In eight statoblasts having thirteen or fourteen hooks the average length of the hook was about .22 mm. ; in the two with sixteen hooks the average length was .19 mm. The figures of statoblasts accompanying this paper will show that at greater extremes the difference in the hooks is still greater.

As the hooks decrease in size with increase in number, we might expect to find the hooks very small in the statoblasts

with many of them. Such apparently is the case, for Oka states that the numerous hooks of *P. gelatinosa* are "minute," projecting beyond the annulus only 0.02 to 0.03 mm.

In studying the hooks, I came across a number of interesting abnormalities that are, indeed, rather common. As already stated, there are typically two claws at the distal end of the

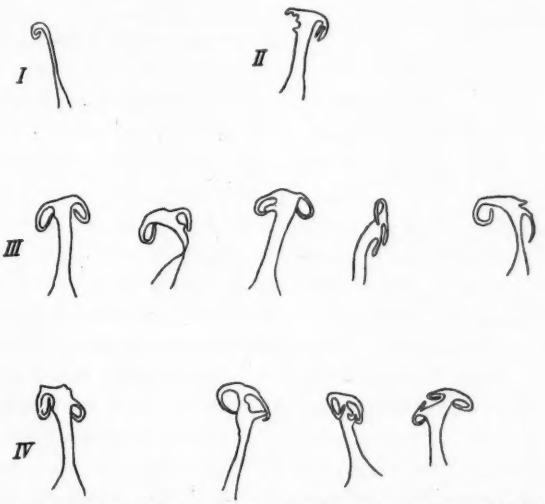

FIG. 9. — Abnormal forms of hooks. *I*, type with only one claw; *II*, type with bifid claw; *III*, type with additional claw on one side, in first four cases below; in last case above, normal; *IV*, type with double outgrowth; in final case a double-headed hook is formed.

hook. The abnormalities concern chiefly these claws. They may be grouped under four types (Fig. 9) :

Type I, only one claw.

Type II, a bifid claw.

Type III, an additional claw — on one side.

Type IV, a double outgrowth on one side — producing in extreme cases a hook with two complete double claws at its distal end.

In addition, very rudimentary hooks, mere thread-like spines, are frequently found, often lying outside the typical marginal row. In *P. gelatinosa* these abnormal hooks are apparently even more common. Oka ('90, Pl. XIX, Fig. 35) has figured some of them. They can for the most part be referred to the same

four types. The abnormal multiplication of claws in Pectinatella is paralleled by the normal condition in Cristatella, where the radial outgrowths of the statoblasts form grapnels with many claws. The condition in Cristatella is in so far different as the claws stand out in all radii in Cristatella, whereas they lie almost or wholly in one plane in the case of Pectinatella. Also "*Pectinatella Carteri*" has "many lateral claws" to each hook.

Both abnormalities and individual deviations from mediocrity in Pectinatella are thus normal or modal in other species of Phylactolæmata.

Summary. — The hooks on 827 statoblasts of a Lake Michigan Pectinatella were counted. The number ranged from 11 to 21; the mode was 13; average, 13.782 ± .031; and index of variability, 1.318 ± .022. The skewness was + 0.077; that is, the variation tends in the direction of the larger numbers, and this is correlated with the fact that species or races of Pectinatella with much larger numbers of hooks occur. There is a slight hereditary tendency in the statoblasts from one colony, about 0.1 when 1 is the maximum inheritance. There is an inverse correlation (of − .092 ± .006) between the number of hooks and the perimeter, and a larger one between number and size of hooks. The number of hooks is thus not determined by room, nor does it seem to be predetermined from an early stage of development of the statoblast. The hooks show abnormalities, some of which resemble the normal condition of hooks in Cristatella.

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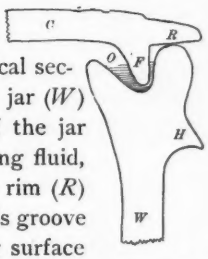
A SEALING STONE JAR FOR ZOÖLOGICAL LABORATORIES.

J. B. JOHNSTON.

THE jar described below was designed as a cheap sealing jar for class use and for the storage of large specimens or of material in quantity for future use. It has been in use since 1898 in three universities in this country, and is now described, since it has proved more satisfactory for the purposes indicated than any other jar known to me. Its cost is inconsiderable when compared with that of glass jars of equal capacity. It has the additional advantages of greater durability and ease of opening and resealing.



The accompanying sketch shows a vertical section of the upper part of the wall of the jar (*W*) and a part of the cover (*C*). The rim of the jar bears a groove (*O*) to be filled with a sealing fluid, indicated by the horizontal shading. The rim (*R*) or edge of the cover projects well beyond this groove to keep out dust. There is upon the under surface of the cover a dependent flange (*F*) fitting into the groove (*O*), so that when the latter is filled with a fluid the jar is sealed. The cover is provided with a knob for lifting, and the rim of the jar, with handles (*H*).

The jars are made by the Zanesville Stoneware Company, Zanesville, Ohio, in the following sizes, inside measurement in inches :

Depth . . .	8	8	12	12	24
Diameter . .	10	12	10	12	12

I have tried a number of sealing fluids before anything suitable for permanent sealing was found. For daily class use it is sufficient to fill the groove with water. Indeed, the mere empty groove reduces the rate of evaporation very considerably, since the alcohol or other vapor must pass downward

to escape beneath the flange. For permanent sealing, glycerine is useless with alcohol, and most available oils "creep" so rapidly that the groove is soon emptied. However, a heavy paraffin oil, obtainable from the Edison Manufacturing Company of New York City, being free from this characteristic, and non-volatile, makes an excellent sealing medium.

WEST VIRGINIA UNIVERSITY, MORGANTOWN,
October 4, 1900.

REVIEWS OF RECENT LITERATURE.

ANTHROPOLOGY.

African Masks and Secret Societies.[1] — The subject is divided ethnographically and ethnologically. That is, the author arranges his material first in geographical order, beginning with South and East Africa and passing through the west coast to the northwest; then upon this material he constructs a historical and racial development in the use and manufacture of masks and in the working of the secret fraternities. For further work the second half, the correctness of the conclusions being assumed, will be the starting point. The introduction to this part presents different analyses of masks and the author's judgments upon these. His conclusion offers some suggestions as to work and methods. The introduction to the second half is in part as follows (p. 157): "Two methods are known of grouping masks in their entirety so as to get a general view of them; either according to their significance or their form. Andree has undertaken the former as follows:

Religious Masks,
War Masks,
Funeral Masks (*Leichenmasken*),
Play and Dance Masks.

This classification has the disadvantage of leaving out of consideration their historical development. Form is not taken into account, and customs are developed like side scenes, without regard to the proper guiding principles of observation. Such a division is more of a benefit to the customs than to the masks when it comes to the determination of the relations between the individual groups. Ratzel has given a classification more appropriate, because less assuming:

A. Simple imitations of the human face.
1. Rough works.
2. Careful copies true to nature.
3. Geometric conventionalizations (*stilisirt*) partly dependent on tattooing.

[1] Frobenius, L. Die Masken und Geheimbünde Afrikas, *Nova Act. Acad. Cæs. Leop.-Carol. Germanicæ. Nat. Cur.*, tome lxxiv (1898), pp. 1–278, Tables I–XIV.

B. Distorted figures, caricatures, scare-faces.

4. Grimaces to arouse mirth or terror; dance or war masks.

C. Animal masks.

D. Head-pieces.

"As may be seen from this arrangement, it deals almost exclusively with the forms from whose nature only occasional conclusions as to their significance can be drawn. Such is an ethnographical view that would be very well in place where geographical relations had been already worked out and where only a collection of the forms of a place, district, or province had to be made. So such tables as Ratzel's are only desirable when convenient to a treating of masks like that of Haddon on those of southeastern New Guinea. For more esoteric work these systems have little value. The method that Dall has used might be considered, and in fact would not be at all bad, if one could convince himself of the truth of his premise, *viz.*, that masks arose from weapons of protection."

Dall's searching classification is then given; it is allowed by the author to be clever, but condemned by the false premise just quoted. Nevertheless, he admits that Dall has shown that the "relations of form and significance, while various, are yet close." The introduction continues: "Every experienced man must have observed from the ethnographic part (of the book) that the African masks compose no simple structure, and that custom and belief are continually influencing the form, changing it and developing it.

"Masks are bound up with particular ceremonies, — they always appear at funeral feasts; where the fraternities begin to disintegrate, masks gain in variety (Cameroon, Loango, Yoruba).

"The classes of head and body masks stand forth clear and distinct: here they are combined, here they are divided. We see derived forms on every hand, as in the bushy circumcision dresses.

"In short, African masks, after examination, attain the appearance of a composite whole, a complicated development, whose several parts are to be traced back to various sources. So it is worth while to note our old point: the form corresponds to the content. Plastic expression, custom, are the forms which owe their existence to the content, to beliefs.

"If we now observe these beliefs and views in origin and growth from their roots up, we shall readily derive the understanding for the various points in our field of study. . . ."

Frobenius then proceeds to derive nearly all African masks and customs from the cult of the dead. Even tree worship arises from

planting a tree on the grave instead of burying the dead in the forest. Hence come sacred posts, stakes, and scepters. Masks refer back to this cult in two ways. First, in some places the dead are buried in peculiar little huts, and hut temples readily arise. An imitation of these "spirit huts" is seen in the tent- or hut-like head coverings, and shoulder- or loin-coverings that form a large chapter in African costumes. It would be hard otherwise to explain the apparent superfluity of clothing in a climate demanding the opposite. The second development is from the human skull: starting from skull dances with the crania tied about the waist, or held whole or in part in the mouth, the transition is easy to skull masks, conventionalized traces of which are to be seen in some of the masks pictured in the text (p. 182).

The work is not too analytic to be interesting; the first part is full of traveler's tales set down by the author (apparently not an African visitor himself) with an Herodotus-like naïveté. The illustrations are numerous and good, but beset with a vicious system of numbering which makes reference a difficult task. There are some misprints in the German, and quite a number in the little English text quoted.

Towards the end the author makes comparisons between the masks and customs of Africa and Oceanica, which prove to him a connection between them, and that the African instances point to more eastern sources.

The conclusion is partly as follows: "It should not be assumed that the subject is exhausted in the present work. Still, no such complete handling has as yet been devoted to the masks of a primitive people. The work may ask for some indulgence from its nature. Whoever wanders in unbeaten paths, as we do here, must often, like the pioneer in his work, find his hand too rough for skilled labor. Therefore many questions are still open and many a fault may have been committed. . . .

"I repeat my often expressed wish to strike out from the scientific order of the day the unhappy nomenclature which so retards progress. Words like 'magician' ('*Zauberer*'), 'fetich,' are essentially superfluous. Their existence naturally gives to the inquirer a false idea of science. He thinks his duty done when he has dubbed an article as of the class of 'fetiches.' I can tell a story about that. I enlightened several missionaries to the effect that by the word 'fetich' absolutely nothing worth while was expressed. These gentlemen thereupon sought for the significance of many of

the amulets of the west coast called 'fetiches.' Behold pages of description and explanation of their use and significance poured in. That was evidence that my desire was justified. . . .

"It seems as if the problem of African philosophy, or, for aught I care, religion, had been so worked over as to be worn out and a bore. Yet the many tomes on fetichism and African religion have brought forth not much more than clever views, — hardly ethnological.

"It now begins to dawn, and the light shows very remarkable and unexpected phenomena. We can only attain clearness if in Africa too inquiry is directed along the new lines. It is an aim of this work to urge on this process. It will be and can be only a pleasure if students and ethnologists tear up the book and discover faults and mistakes; up and forward! The ethnological part will be justified if it only offers inducement to zealous coöperation and energetic progress."

CHARLES PEABODY.

Ancient Crania from the Valley of the Rhone. — Dr. Pittard[1] has published a summary of his investigations upon a large series of ancient Valaisian crania. After an exhaustive comparison of the crania of the two sexes he reaches the following conclusions:

1. In the auricular angles the female skull surpasses the male by the absolute size of the frontal angle, by the size of the two occipital angles — cerebral as well as cerebellar.

2. In the curves the various segments of the skull are larger in the male.

3. The weight of the male skull is absolutely greater, as is also the cranial capacity; but relatively the female skull has greater capacity in proportion to its weight.

4. In relation to their total horizontal circumference the female skulls have a greater capacity than the male.

5. The principal cerebral diameters are better developed in proportion to the cranial capacity in the female skulls.

6. The frontal breadth is greater relatively to the facial breadth in the females.

7. On the other hand, the parietal region is less developed in the female skull if compared with the horizontal circumference and the true cerebral curve.

8. In the female skull the frontal is more vertical, the nasal aperture is larger, and the orbits higher.

[1] Pittard, Eugène. Quelques Comparaisons Sexuelles du Crânes Anciens de la Vallée du Rhone, *L'Anthropologie*, tome ix, No. 2.

9. It is by the frontal breadth and in a lesser degree by the maximum transverse breadth that the female skull approaches most closely to the male; it is farthest from the male skull in the basal region and in the face; the forehead is larger relatively to the face than among the male skulls.

"In conclusion, the above researches, incomplete as they are, demonstrate that the female skull has, in relation to the male cranium, a frontal type, as has been shown already by M. Manouvrier, and that the cranial capacity is relatively greater." It is to be remembered that these results were obtained from the study of a brachycephalic series of crania.

Notes. — Dr. R. Verneau (*L'Anthropologie*, Tome IX, p. 2) figures and describes a new instrument for measuring cranial angles and diameters. The advantages claimed by the inventor for this new apparatus are that:

1. It renders measurements comparable by always securing the parts in the same relative position.
2. The projections can be quickly measured which heretofore have been obtained by geometric drawings.
3. Both vertical and horizontal projections can be taken at the same time.
4. All the dihedral angles relating to one horizontal plane can be directly measured.

We have received reprints of two papers by Mr. James Mooney of interest to ethnologists and students of American history. "The Cherokee River Cult" was published in the *Journal of American Folklore*, Vol. XIII. The peculiarly sacred character of the flowing stream to the primitive mind is explained, and a number of formulas used by the native priests when invoking the aid of the river-god are translated.

Reprinted from the *American Anthropologist* of July, 1899, is an account of "The End of the Natchez." Mr. Mooney devotes himself especially to the history of the tribe subsequent to the year 1730, when they were broken and dispersed by the French. Perhaps twenty individuals belonging to this tribe survive, all living in the Indian Territory with the Creeks.

In the *Proceedings of the American Antiquarian Society*, Vol. XIII, 1900, is published a paper by Mr. Lucien Carr upon "The Mascoutins." The history and even the identity of this tribe has been

uncertain. Mr. Carr shows that they were a branch of the Shawnee division of the Algonquian stock that was finally absorbed by another branch, the Kickapoos.

F. R.

GENERAL BIOLOGY.

Biology of Crystals.[1] — From biology to the structure of crystals seems a far cry, but those who have penetrated farthest in the study of organisms have time and time again come to the borderland of the inorganic realm. Most have declined to go over into the untraveled domain of a foreign country. Professor Bütschli is not one of these. His studies on the structure of protoplasm are the most profound that have been made. They led him to recognize a single fundamental protoplasmic structure, — the alveolar or "foam" structure, — of which the karyokinetic figures are only special expressions. At the time of his early discoveries there were few inorganic substances which were known to have any such structure. Emulsions alone were comparable. Studies of starch, cellulose, and chitin revealed to Bütschli a similar alveolar structure, and now he has continued his researches into crystals of sulphur and certain salts and finds here the same structure. The protoplasmic structure is, then, not something peculiar to living substance, but is probably characteristic of substance in general — at least of changing, forming, growing substance. Moreover, in the forming crystal we have radial lines proceeding from a center, and these are *structurally* like the radiations of the asters — like, because due in both cases to a central pull exerted on an alveolar structure.

The vast mass of the work deals with matters of interest, first of all, to crystallographers and physical chemists — the microscopic details of crystal formation, the polymorphism in crystallization, the determination of the polymorphic form by external conditions. These are matters which will be eagerly read by the biologist also, a few years hence, when the close and fundamental relations between organic development and crystalline development become more generally appreciated.

C. B. D.

[1] Bütschli, O. *Untersuchungen über Microstrukturen des erstarrten Schwefels, nebst Bemerkungen über Sublimation, Überschmelzung und Übersättigung des Schwefels und einiger anderer Körper.* Leipzig, Engelmann, 1900. Quarto, 96 pp., 4 pls., 6 figs.

Finding Flaws. — Every scientific man knows that science is progressing and ideas are changing. Aristotle's writings on animals read strangely to-day, but we are not therefore to lay stress on his limitations. Darwin wrote the first edition of the *Origin of Species* over forty years ago, and it would be strange indeed if every part of it were acceptable to-day. Every bit of Darwin's earlier evolutionary writings was not acceptable to Darwin himself before he died — a fact to be put down to his credit. The author of this book[1] devotes over three hundred pages to pointing out Darwin's changes of views, "special errors and inconsistencies," "looseness and contradictions." Some of the "flaws" which the author holds up to view and takes great delight in pointing to again and again belong to the category of natural advances in knowledge; others are still debatable points; in other cases the author seems to be straining things to make a point. The worst of it is that the whole book is written in a style of oiled fluency, cocksureness, and conceit, which makes the reader doubt the author's sincerity. Thus on page 193:

> I have tried to understand many things, but Mr. Darwin I cannot understand. You cannot have "uniformity of conditions" and uniformitarianism of process and result too; for the one is based on fixity and the other on fluctuation — it may be slow, but ceaseless — though it may be very, very slow, yet also of a necessity very, very sure. Hegel's Absolute was always a becoming; phenomena, conditions, are always a-coming and a-going; it is because of this that they are phenomena and conditions, and to have to write thus in the year of grace 1899, in reference to the work not only of a great naturalist but of a thinker, makes me rather ashamed of falling back so much and so fully on what I was well taught in the logic and metaphysic class-room of Edinburgh University by the worthy successor of Sir William Hamilton, "forty years ago, my boys, forty years ago."

But after all, if only one can be undisturbed by these personal things, he will find in the book many interesting facts which the author has collected and which are new to speculative books of this sort.

Recent Work in Electrotaxis. — In two papers[2] published within the year, Dr. Oskar Carlgren has considerably advanced our

[1] Alexander, P. V. *Darwin and Darwinism, Pure and Mixed.* A Criticism, with Some Suggestions. London, John Bole, Sons, and Danielson, 1899. 346 pp.

[2] Carlgren, O. Ueber die Einwirkung des constanten galvanischen Stromes auf niedere Organismen, *Arch. Anat. u. Physiol.*, Physiol. Abth., 1900, pp. 49–76.

Carlgren, O. Ueber die Einwirkung u. s. w.: Zweite Mittheilung: Versuche an verschiedenen Entwicklungsstadien einiger Evertebraten, *Arch. Anat. u. Physiol.*, Physiol. Abth., 1900, pp. 465–480.

knowledge in regard to the action of the constant electric current on lower organisms. The work bears evidence of having been carefully and well done. The first of the two papers is principally given to a description of the electrotactic reactions of Volvox, introduced by a brief account of the normal movements of the animals based largely on the results of Klein and Rösel. He finds the sense of the response to the current to be kathodic immediately after the circuit is completed. After the current has been passing for some time, however, this kathodic response becomes less and less evident, until finally there ensues a more or less distinct anodic movement; but this latter never becomes so well marked as the previous motion towards the kathode. If the Volvox is placed in a thin gelatine solution, so that it remains alive but is unable to move, very striking changes in the form of the body accompany the action of the current. The anode side of the colony becomes wrinkled and crumpled together, while the kathode side is correspondingly swollen out. These phenomena become more apparent the longer the current acts, and take place without relation to the orientation of the axis of the body with reference to the current direction. At the same time all the parthenogonidia move towards the anode side of the colony. This movement is evidently an entirely passive one, since it occurs regularly in all stages of their development, as well before they are able to move actively as after. That the change in body form is of a purely passive character is evidenced by the fact that it takes place in the same way in colonies which have been killed in formalin. To extend the results the effect of the current was tried on lifeless individuals of *Paramecium aurelia* and *bursaria*, *Colpidium colpoda*, and Amœbæ of different species, and in all these cases there resulted the anode crumpling and the kathode swelling. In his theoretical discussion Carlgren advances the view that the effect of the current on organisms is to a certain extent of a purely physical nature. He believes that this physical action is of extreme importance, but does not attempt to make it account for all the facts. His results make it evident that in any future work on the subject this factor must at least be considered.

In the second paper there is a detailed account of the electrotactic response of the larvæ and embryos of a number of marine invertebrates. The point of greatest general interest is in regard to the reactions of the larvæ of certain echinoderms (*Strongylocentrotus lividus*, *Sphærechinus granularis*, *Ophiotrix fragilis*, and *Asteracanthion glacialis*). Young free-swimming stages of these animals gave

no response whatever. Older larvæ, Plutei and Bipennariæ, became oriented in stronger currents and went to the kathode. Again at a later stage of development the electrotaxis completely disappears. All theoretical discussion of the results is left for a future paper.

In view of the character of the papers here reviewed, particularly the first, further work along the same lines by Dr. Carlgren will be awaited with interest.

RAYMOND PEARL.

ZOÖLOGY.

An Introduction to Zoölogy.[1] — In twenty chapters the authors take up successively the grasshopper, the butterfly, the beetle, the fly, the lithobius, the spider, the crayfish, daphnia, the earthworm, nereis, the slug, the fresh-water clam, the starfish, the hydra, paramœcium, the smelt, the newt, the lizard, the English sparrow, the mouse. In each the type and "its allies" are described from a general natural-history standpoint and with an appended key to the chief representatives of the group. A last chapter deals briefly with the development of the frog's egg.

Then in one appendix we find the stimulating outlines of laboratory work upon each of the above twenty-one forms that was proposed for entrance requirement at the Lawrence Scientific School, Harvard University. A second enumerates more than one hundred works and papers of reference; and a third gives a useful classification of the animal kingdom, with brief distinguishing characters of larger groups and references to the pages of this work, in which orders and families are mentioned. An index and glossary conclude the four hundred and twelve pages.

The book is well described in the preface: "The general plan of this text-book is at the same time both old and new. Old, because it attempts to restore the old-time instruction in Natural History; new, because Natural History is not to-day what it was a generation ago. The treatment will seem new also in contrast with modern text-books of zoölogy, since they are devoted primarily to comparative anatomy, a field upon which we lay little stress. . . . It is a guide to the study of animals, which it is hoped may introduce many

[1] Davenport, C. B. and G. C. *Introduction to Zoölogy.* A Guide to the Study of Animals, for the use of Secondary Schools. New York, Macmillan, 1900. xii + 412 pp., 306 figs.

students to the sciences of comparative anatomy, comparative embryology, cytology, general physiology, variation and inheritance, and the others that are grouped under 'zoölogy.' This book is like a 'Synoptic Room' in the vestibule of a vast museum, containing the most essential things for those who can go in but a little way, but also fundamental for those who can penetrate farther."

This Natural History, vivified by general physiology, seems worthy to replace many of the school text-books now in use, if only the teacher be prepared to make the field and laboratory work dominate over the "cram" which presentation of so many facts makes an opening for.

The three hundred and eleven illustrations are a most important feature, remarkable in that the majority are from original photographs. Many of these are excellent, and, as the authors state, "their publication may be considered as something of a contribution to science." Yet it is to be regretted that, in some illustrations of invertebrates, black photographs have been preferred to good drawings; while, on the other hand, in the higher groups, notably the mammals, drawings of stuffed specimens have been used, where photographs from life, such as those of Gambier Bolton, might have been used to advantage.

We hope the book will meet with a success that will insure revisions. Meanwhile, the "blue crab" figured on page 109 will be of peculiar interest to the specialist.

E. A. A.

Merogeny. — The notable work of Yves Delage, first published in the *Comptes Rendus*, October, 1898, and in detail in the *Archives de Zoologie Experimentale*, VII, Nos. 3 and 4, 1899, widens the field of experimental research by a new method, and adds facts difficult to assimilate with the current conceptions of the phenomena of fertilization.

In the echinoderms *Strongylocentrotus lividus* and *Echinus sp.*, in the mollusk Dentalium, and in the annelid *Lanice conchylega*, he has succeeded in cutting eggs into two or more pieces and in keeping these pieces under observation in drops of water till they developed into the characteristic larvæ of these groups. In each case sperm was added, and it is inferred that it entered and fertilized the pieces. Moreover, in some echinoderm eggs the egg nucleus was seen in one piece and not in the other; yet the piece with no nucleus formed a larva just as well as did the piece with a nucleus. It is inferred that most of the fragments were without nuclei.

This development of fertilized, enucleated pieces of eggs the author calls merogenetic development.

In cleaving, such fragments tend to be abnormal at first, but by progressive self-regulation normal larvæ are formed.

In the sea-urchin three larvæ were got from one egg, and in another case an active blastula was obtained from a piece of egg one-thirty-seventh of the bulk of the normal egg.

In this well-controlled Gallic method of cutting a single egg while under observation under the microscope we seem much more sure of the results than in the former gross Teutonic method of shaking eggs wholesale in a tube, to break them to pieces. Still, the author finds it necessary to give reasons for rejecting the ideas, — that the egg was fertilized before cutting; that the cutting itself acted as a stimulus; and that the nucleus might have been cut to supply parts to each piece of egg.

In this he seems successful, except as to the last point, and we may still have doubts regarding the assumed restriction of the nucleus, or the nuclear matter, to one of the pieces. Another possibility, or indeed probability, the occurrence of polyspermy in these fragments, seems to have escaped the author's attention. This may vitiate some of his most important conclusions.

Incidentally the author points out that the cut halves of an egg may be drawn together again by the viscous envelope (we presume Hammar's layer) that is not necessarily severed. There is no evidence of "cytotropism" in this. On the other hand, there is often an abnormal tendency of the blastomeres to fall apart; we infer this is a state similar to that induced by Herbst in removing calcium.

It is interesting to find that the enucleated pieces may be bastardized by sperm of a related animal, but they do not develop when treated with the sperm of a widely different animal. In this the author sees the importance of the cytoplasm; and he also finds evidence of a maturation of the cytoplasm. Thus a ripe and an unripe egg in two drops on the same slide, when cut and treated with sperm, yielded for the ripe egg cleaving pieces in six out of ten cases, and none at all in the unripe eggs.

Granting that these merogenic larvæ are actually fertilized, enucleated pieces of an egg, it is a very remarkable fact that they have eighteen chromosomes in the nuclei of their cells, for this is the normal number that is commonly held to have come about by the addition of nine chromosomes in the sperm to nine in the nucleus of

the egg, yet in this case we start with only the nine of the sperm and have no egg nucleus at all in the fragment studied. Delage concludes that the constant number of chromosomes, *n*, is a constant factor of the cells, as are the contractile or secretive functions of cells, and that it is not produced by the activities of chromosomes acting as individuals.

In the last paper he defines his position as to the meaning and nature of fertilization. Assuming that experiment has shown that a piece of egg protoplasm, with no nucleus, can form an embryo if combined with a sperm, and not otherwise, he affirms that the essential thing in fertilization is this union of egg cytoplasm with the sperm. The egg nucleus is not necessary for the formation of a larva. Moreover, his experiments show that the per cent of fragments developing is larger than the per cent of whole eggs developing under given conditions, and he infers that the egg nucleus is not only unnecessary, but even a hindrance to fertilization.

In normal fertilization he regards the nuclear phenomena as rather a *substitution* of a male for a female nucleus than as a combination of the two. He does not deny that the egg nucleus is of use to the race in aiding in handing down characters of the maternal side, it may be; but to the making of the individual it is not useful, but detrimental.

Accepting the recent experiments upon echinoderm eggs, in which they are stimulated by chemical agents to develop parthenogenetically, he supposes that in fertilization the sperm nucleus is the active stimulating factor, while the egg nucleus is inert — to such an extent as to inhibit the sperm to some extent. Extending this idea, he supposes that the process of maturation of the egg is to be interpreted as follows. The polar bodies take from the egg nuclear matter and so reduce the inertness of the egg nucleus to a point where the sperm may overcome what is left. Were there no polar bodies, the sperm could not overcome the inertness of the entire egg nucleus.

E. A. A.

Skeleton of the Black Bass. — The skeleton of the black bass, on which Dr. Shufeldt has already made several interesting reports, has been described by him in full in a recent memoir.[1] This is accompanied by eight well-executed figures which illustrate in particular the structure of the skull of this fish. The text includes

[1] Shufeldt, R. W. The Skeleton of the Black Bass, *U. S. Fish Comm. Bulletin for 1899*, pp. 311–320. 1900.

some elementary directions as to methods of preparation and study, as well as a description of the parts under consideration, and is written from the standpoint of the older anatomy. Thus the statement is made that the black bass seems invariably to have thirty vertebræ, though in a former count the author reported thirty-two. His present changed opinion rests on the examination, as he tells us, of two perfect specimens, a rather limited number on which to base a general statement, and certainly not sufficient to show that the former count of thirty-two may not at times be realized. The modern anatomist is beginning to appreciate the fact that perfect uniformity in the number of parts is rather the exception than the rule, and that the truth of the matter is often better expressed in statements indicative of the range of variation in structures than in careful descriptions of them from one or two individuals. In this respect Dr. Shufeldt's work belongs to the older school.

P.

Skeleton of Vulpes Macrotis. — The fact that the skeletons of none of our smaller western foxes have ever been fully described has led Dr. Shufeldt[1] to prepare an account of the osteology of *Vulpes macrotis*. The description is taken from a single specimen collected in Arizona and now in Dr. Shufeldt's possession. An exhaustive study has brought to light many points of resemblance and difference in the skeleton of this species as compared with those of closely allied forms, but without disclosing any important morphological matters. In the account of the skull, Dr. Shufeldt takes the late Dr. Elliott Coues to task for having systematically ignored the turbinal masses, and yet lays himself open to the same criticism by giving no description of these parts in the animal under consideration. To the scientific reader the text is somewhat marred by insertions such as those pertaining to the clavicles. These bones were missing in the specimen described by Dr. Shufeldt, and yet the reader is informed that "there is every reason to suppose that they agreed in their general character with the vulpine carnivora generally; that is, in some respects they were rudimentary and did not reach either the acromion or the sternum." Statements of this kind add nothing of importance to osteological descriptions such as this paper abounds in, and tend to discredit what is otherwise a commendable collection of anatomical details.

P.

[1] Shufeldt, R. W. The Osteology of Vulpes Macrotis. *Journ. Acad. Nat. Sci. Philadelphia.* Vol. XI, pp. 393–418, Pls. XXII, XXIII. 1900.

Notes. — Professor M. M. Metcalf's extended studies on the tunicates have been published in the *Zoölogische Jahrbücher* as a series of short articles under the general heading "Notes on the Morphology of the Tunicata."

On the basis of recent studies on the life history of certain gregarines, Léger and Dubosca (*C. R. Acad. Sci. Paris*, 5 Juin, 1900) find that the epimerite alone is intracellular, and maintain that, contrary to generally accepted views, a true intracellular stage in development is very exceptional among these forms.

A detailed description of two fish tapeworms from the Great Lakes is given by Benedict (*Journ. Morph.*, Vol. XVI, pp. 337–368, 1 pl.). One is a well-known European form, and the other an imperfectly known species originally described by Leidy. Both belong to the genus Proteocephalus Weinland (= Ichthyotænia Lönnberg), which is shown to be more complicated in structure than hitherto supposed.

In his chapter on the entozoa, in the *Fauna Hawaiiensis* (Vol. II, Pt. IV, pp. 427–441, 2 pls.), Shipley reprints with emendations the description of the peculiar form *Apororhynchus* (= *Arhynchus*) *hemignathi* which he had previously discussed. It is important as the only known Acanthocephalon with no trace of the evertible proboscis and hooks ordinarily accepted as characteristic of the group.

A number of new genera of North American Hydrachnidæ are described and figured by Wolcott (*Trans. Amer. Micr. Soc.*, Vol. XXI, pp. 177–200, 4 pls.). The only one in the list which was previously known was reported once each from Russia and Venezuela, and is exceedingly aberrant in structure.

A new cestode of peculiar structure has been found in the turkey and is described by Ransom (*Trans. Amer. Micr. Soc.*, Vol. XXI, pp. 213–226, 2 pls.). It is characterized by the migration of the eggs in masses from the uterus to a point nearer the center of the proglottid, where a prominent egg capsule is secondarily constructed to include them. The uterus then becomes reduced, until it disappears entirely, — whence the name given to the form, *Metrolias-thes lucida*.

The plankton of Echo River, Mammoth Cave, Kentucky, as listed by Kofoid (*Trans. Amer. Micr. Soc.*, Vol. XXI, pp. 113–126) from collections made by Eigenmann, is characterized by absence of plant life, particularly diatoms, by absence of rotifers, by predominance of

copepods, and by the presence of many littoral species. Among all the forms listed, twenty in all, few, if indeed any at all, are stygian, while most are common epigean forms. The author thinks that free access of surface water provides for the renewal of the plankton and prevents the development of peculiar cave forms.

The annelids of the Nordenskjöld expedition to Patagonia have been studied by Ehlers (*Nachr. Ges. Wiss.*, Göttingen, 1900, Heft 2). The collection embraced eighty-four species, of which twenty-one were new, and supplements well that made by Michaelsen in the same region. Three species and two varieties are noted as characteristically "bipolar" in distribution so far as known at present.

Jägerskiöld has given (*Centralb. Bakt.*, 1 Abt., Vol. XXIV, p. 737) a valuable discussion of the curious rosette organs of the lateral line in ascarids. Though exceedingly variable in different species, they are undoubtedly homologous; their function must still be left uncertain, though size and development show them to be active and important.

Van Denburgh and Wight (*Amer. Journ. of Phys.*, Vol. IV, p. 209) have studied the more important effects of the poison of the Gila Monster (*Heloderma suspectum*). A subcutaneous injection of six or seven drops into the groin of a dog was followed by death in less than twenty-four hours. Observations on numerous cases showed that the poison acted directly upon the respiratory center, causing a quickening and then a gradual paralysis of the respiratory mechanism. When artificial respiration was resorted to, death nevertheless supervened as a result of cardiac failure, showing that the heart is profoundly affected as well as the respiratory apparatus. The authors conclude that the effects of the Gila Monster poison are in no important respect different from those of the venom of various poisonous snakes.

H. M. Vernon (*Phil. Trans. Roy. Soc.*, 1898) brings additional evidence to that furnished by Seeliger and by Morgan to show that Boveri's (*American Naturalist*, March, 1893 and 1895) famous attempt to establish by experiment the dependence of adult characters upon chromosomes did not rest upon a firm basis. He finds that in the echinoderms bastards resemble now one parent, now the other, according to the time of year in which the crossing was carried on. He concludes that the "characteristics of the hybrid offspring depend directly upon the relative degrees of maturity of the sexual products."

The Oregon State Biologist, Professor F. L. Washburn, has just published a brief illustrated account of the food fishes of the Oregon coast. The pamphlet includes brief descriptions of some dozen food fishes, accompanied by photographic and other illustrations, and marks a beginning in the systematic study of the food fishes of the state.

BOTANY.

Mrs. Dana's Wild Flowers.[1] — Mrs. Dana's now well-known book owes its inspiration to an idea of Mr. Burroughs', that some day a book would appear by which our wild flowers should be made known without the trouble of analyzing them; and his suggestion of color and season as the leading means of attaining this seemingly desirable end has been faithfully worked out in it. Seven years have elapsed since the first edition appeared, and the fact that the edition now under review marks the issuance of the fifty-sixth thousand shows that it has met with measurable favor. Opinions have differed as to its real value. People who love but do not know flowers, and who want to learn their names without trouble, have always liked it. People who believe that one might as well learn botany while learning the names of the commoner and more showy plants have not infrequently regretted its publication. While the present reviewer would not start a student of botany with it, he believes it to be a very good book of its kind and for persons who will not go at the study in more than a holiday spirit, and it is a delight to thumb its pages. It may be that the numerous colored plates which form the novel feature of the new edition add to the value of the book, and they certainly are well done for three-color work, and will add to its salability.

T.

Our Native Trees.[2] — Miss Keeler has made a very commendable addition to the semi-popular treatises on American plants, in a

[1] Dana, Mrs. W. S. *How to Know the Wild Flowers.* A Guide to the Names, Haunts, and Habits of our Common Wild Flowers. Illustrated by Marian Satterlee and Elsie Louise Shaw. New edition, with colored plates. New York, Charles Scribner's Sons, 1900. 8vo, xxxix + 346 pp.

[2] Keeler, Harriet L. *On Native Trees and How to Identify Them.* A Popular Study of their Habits and their Peculiarities. New York, Charles Scribner's Sons, 1900. 8vo, xxiii + 533 pp., with 178 illustrations from photographs and 162 illustrations from drawings.

well-written, well-illustrated, and well-printed account of the native and naturalized trees of the "Manual" region. Bits of the best from poets and prose-writers relieve the monotony of description, and the folklore of a number of trees is well if briefly told. T.

Clements and Cutler's Manual.[1] — Dr. Bessey has long taken not only a theoretical but a very practical interest in secondary school training in the sciences, and the Nebraska high schools are reaching the point where their graduates can be said as a class to be better prepared for the real and serious study of botany for having had botany before entering college. Dr. Clements, of the University of Nebraska, and Mr. Cutler, of the Beatrice High School, have prepared this little book as an authoritative expression from the University upon the desirable kind and amount of such preparatory study. And while its use is likely to be limited to Nebraska, it may well find place in the working library of any high school. T.

Notes. — "The Plant Covering of Ocracoke Island," a study in the ecology of the North Carolina strand vegetation, by Thomas H. Kearney, Jr., constitutes No. 5 of the current volume of *Contributions from the United States National Herbarium.* It is illustrated by a number of figures in the text, representing structural adaptations.

A paper by R. M. Harper, on the flora of Sumter County, Georgia, appears in the *Bulletin of the Torrey Botanical Club* for August. Ecological lists, of some four hundred or five hundred species, are followed by critical notes on a considerable number of the species.

A systematic key to the phanerogamic spring flora of Kansas City and vicinity has been prepared by Kenneth K. Mackenzie, for use in the high schools of that city, and is published as an octavo pamphlet of twenty-three pages.

In the *Botanical Gazette* for September, Professor Nelson begins a series of "Contributions from the Rocky Mountain Herbarium," consisting of descriptions and critical notes on species and varieties believed to be undescribed.

Part IV of Professor Piper's "New and Noteworthy Northwestern Plants," in the July *Bulletin of the Torrey Botanical Club*, contains a considerable number of new species, of various dicotyledonous groups.

[1] Clements, F. E., and Cutler, I. S. A Laboratory Manual of High School Botany. Lincoln, Nebraska, The University Publishing Company, 1900. 8vo, 123 pp.

With fascicle 124, issued in April, Part III of Vol. XIII of the *Flora Brasiliensis* is brought to a conclusion, with title-page and index. The volume includes the natural families Polygalaceæ, Turneraceæ, Caricaceæ, Loasaceæ, and Sapindaceæ.

The third part of a series of papers on Mexican materia medica, by a number of students, has recently been issued by the *Instituto Médico Nacional*, of the City of Mexico.

In *Publication No. 50* of the Field Columbian Museum, Dr. Millspaugh publishes a reconsideration of the Cyperaceæ and of Cakile as treated in his earlier paper on the Antillean cruise of Mr. Armour's yacht *Utowana*, in the West Indian and Central American region.

A catalogue of plants collected by Don José Blain on the Isle of Pines, Cuba, is published by Dr. Millspaugh as *Publication No. 48* of the Field Columbian Museum.

The synonymy of several North American species of Eryngium is reviewed by Britten and Baker in a recent number of the *Journal of Botany*.

Part III of Mrs. Brandegee's "Notes on Cacteæ" is published in *Zoe* for July.

Von Seemen describes two Colorado willows, supposed to be new, in Heft 2 of Vol. XXIX of Engler's *Botanische Jahrbücher*.

Hydastylus, a genus proposed in 1812 by Dryander and Salisbury for the plant which has commonly been known as *Sisyrinchium Californicum*, is revived by Bicknell in the *Bulletin of the Torrey Botanical Club* for July, and is now made to include twelve species, all of Mexico or the Pacific United States.

Recent numbers of the *Acta Horti Petropolitani* are largely occupied by papers on Orchidaceæ, by Klinge.

Exoascus deformans, and the means of controlling the leaf-curl of the peach due to it, form the subject of an extensive bulletin by Newton B. Pierce, recently published by the United States Department of Agriculture.

Variation among pathogenic bacteria, a fruitful subject for study, is considered by Dr. Theobald Smith in a paper recently reprinted from the *Journal of the Boston Society of Medical Sciences*. From the seeming fact that new disease germs are not constantly

appearing, Dr. Smith argues that most species cannot adapt themselves to a parasitic existence, but that the many germ diseases are due to a comparatively small number of primary species, endowed from the beginning with certain fighting or invasive characters, and subsequently adapted to various hosts.

Mr. E. S. Salmon's recent monograph of the Erysiphaceæ, in the *Memoirs of the Torrey Botanical Club*, is followed in the August number of the *Bulletin* of the same society by a paper on the Japanese representatives of the same group, with a host-index.

The interesting smut genus *Mycosyrinx* forms the subject of a paper by Penzig in a recent number of *Malpighia.*

Notwithstanding his advanced age, Professor Oudemans continues his studies of fungi, and has recently distributed the first of a series of "Contributions to the Knowledge of Some Undescribed or Imperfectly Known Fungi" (in English) from the *Proceedings of the Royal Academy* of Amsterdam.

The needs of a young and growing botanical garden are modestly stated in the August number of the *Journal of the New York Botanical Garden.*

"A Study of Plant Adaptations" is the title of *Bulletin 69* of the Rhode Island Agricultural Experiment Station.

PUBLICATIONS RECEIVED.

(Regular exchanges are not included.)

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(*No. 407 was mailed November 26, 1900.*)